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ARMY PRELIMINARY EVALUATION YAH-1R IMPROVED COBRA AGILITY AND MANEUVERABILITY HELICOPTER

ADDENDUM
FINAL REPORT

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was conducted

The United States Army Aviation Engineering Flight Activity (USAAEFA) conducted follow-on testing of the YAH-1R helicopter subsequent to the Army Preliminary Evaluation (APE) of that aircraft. These tests were to investigate problem areas discovered during previous testing and to complete certain tests deleted from the airworthiness and flight characteristics tests of the YAH-1S because of inclement weather. These follow-on tests were conducted, using aircraft serial

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(cont fr p1473A) ——> In the six test flights, emphasis

20. Abstract

number 70-15936, at the Bell Helicopter Company facility at Arlington, Texas, between 28 April and 5 May 1975. Six test flights were flown for a total of 5.6 flight hours, 4.5 of which were productive. Emphasis was placed on evaluating maneuvering stability in high-speed diving flight and on investigation of engine/rotor system static and dynamic droop characteristics. The test results reported in this report presuppose that the reader is familiar with and has access to the APE report. This report is intended to amplify and expand the APE report and is not ~~intended to be~~ a rewrite of that APE report. In a dive at 155 ~~knots indicated airspeed~~ KIAS, the YAH-1R was found to have stable maneuvering stability at normal load factors below 1.4 and neutral maneuvering stability at load factors above 1.4. The engine/rotor system static and dynamic droop characteristics were unaltered from those described in the APE report (USAAEFA Project No. 74-33). The attempt to quantify the engine/rotor dynamic response met with limited success due to installed instrumentation limitations and lack of precisely defined flight test and data analysis techniques. In response to requests made during the formal debriefing of this evaluation conducted by USAAEFA personnel, the ~~United States~~ Army Aviation Systems Command acted to increase the engine output shaft speed limit to 6900 rpm for 10 seconds independent of power. This new proposed engine limit greatly reduces the pilot workload during rapid deceleration maneuvers; however, the engine/rotor speed increase was unaltered and thus remains ~~as~~ a shortcoming. Continued testing using fully instrumented aircraft to develop suitable engine/rotor system test techniques and data analysis methods was recommended. No additional deficiencies or shortcomings were determined during this evaluation; The conclusions of the APE report were unaltered.

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INTRODUCTION

BACKGROUND

1. In early 1972, development was initiated for an improved Cobra armament system (ICAS) to upgrade the AH-1G helicopter to meet the requirements for an armed helicopter in a mid- and high-intensity warfare environment. An airworthiness and flight characteristics (A&FC) evaluation was conducted on a prototype ICAS helicopter, designated the AH-1Q, from April through June 1973 (ref 1, app A). Subsequent analysis of the AH-1Q mission indicated a requirement for improved Cobra agility and maneuverability (ICAM). To meet the requirements for ICAM, the Bell Helicopter Company (BHC) developed two prototype helicopters designated the YAH-1R and YAH-1S, differing only in armament configuration. In January 1975, the United States Army Aviation Systems Command (AVSCOM) directed the United States Army Aviation Engineering Flight Activity (USAAEFA) to perform an Army Preliminary Evaluation (APE) of the YAH-1R and an A&FC evaluation of the YAH-1S. These evaluations were conducted from February through April 1975. The YAH-1R APE revealed flight characteristics requiring further evaluation (ref 2) and, due to inclement weather at the test site, the YAH-1S A&FC evaluation was not entirely completed. Therefore, AVSCOM subsequently directed that USAAEFA conduct follow-on tests of the YAH-1R in accordance with references 3, 4, and 5.

TEST OBJECTIVES

2. The objectives of the YAH-1R follow-on testing were as follows:

a. To complete flight tests not accomplished on the YAH-1S due to inclement weather at the test site.

b. To conduct further flight testing into problem areas discovered during the YAH-1R APE.

DESCRIPTION

3. The YAH-1R helicopter is manufactured by BHC and is a modified version of the AH-1G helicopter. The YAH-1R is a tandem, two-place, single-lifting-rotor attack helicopter equipped with a Model 212 tail rotor and is identical in appearance and overall dimensions to the AH-1G helicopter except for those dimensions pertaining to the tail rotor. A detailed description of the AH-1G helicopter is contained in the operator's manual (ref 6, app A). A detailed description of the Model 212 tail rotor is contained in USAASTA Final Report No. 72-30 (ref 7). Internal modifications applied to the AH-1G to develop the YAH-1R model include the following:

a. Installation of a T53-L-703 engine with a thermodynamic rating of 1800 shaft horsepower (shp) and an engine torque limit of 1175 foot-pound (ft-lb) (1500 shp).

b. Installation of an uprated main transmission rated at 1290 shp for 30 minutes and 1134 shp for continuous operation.

c. Installation of an uprated tail rotor drive system rated at 187 shp continuous and up to 260 shp for 4 seconds as a transient power limit and incorporation of a Model 212 tail rotor.

d. Incorporation of strengthened transmission mounts and associated structures, and tail boom.

e. Installation of push-pull tubes replacing cables in the tail rotor control system.

f. An estimated increase in empty weight of 61 pounds.

g. An increase in the maximum allowable gross weight from 9500 to 10,000 pounds.

4. Appendix B of the APE report provides a detailed description of the modifications listed above and photographs of the test helicopter (serial number 70-15936).

TEST SCOPE

5. The YAH-1R follow-on tests were conducted at the BHC flight test facility, Arlington, Texas (elevation 630 feet), from 28 April through 5 May 1975. During the evaluation 6 flights were conducted for a total of 5.6 hours, of which 4.5 hours were productive. All flights were conducted in the Hog configuration (four loaded XM200 2.75-inch rocket launchers mounted on the wing stores stations, M28-A1 turret guns in the stowed position). The helicopter was evaluated for the attack helicopter mission and against the requirements of military specification MIL-H-8501A (ref 8, app A), including applicable instrument flight requirements. Instrumentation, data reduction support, and aircraft maintenance were provided by BHC. Takeoff gross weight for all flights was 10,300 pounds to achieve an average flight gross weight of approximately 10,000 pounds. Testing was conducted at both forward and aft extremes of the longitudinal center-of-gravity (cg) envelope (191.9 to 199.6 inches at 10,000 pounds gross weight). All tests were conducted with a trim main rotor speed of 324 rpm and/or 6600 rpm engine output shaft speed. Test conditions are shown in table 1. Flight restrictions and operating limitations presented in the AH-1G operator's manual as modified by AVSCOM (ref 5), the safety-of-flight release for the YAH-1S (ref 9), and the proposed YAH-1R supplement (ref 10) to the operator's manual were observed.

Table 1. Test Conditions.

Test	Average Gross Weight (lb)	Average Longitudinal Center-of-Gravity Location (in.)	Average Trim Calibrated Airspeed (kt)	Average Density Altitude (ft)	Average Outside Air Temperature (°C)	Remarks[1]
Static longitudinal stability	9580	192.1 (fwd)	155	5500	17.0	Diving flight
Static lateral-directional stability	9480	192.1 (fwd)	155	5400	17.5	Diving flight
Maneuvering stability	9970	199.4 (aft)	60	4900	16.0	Level flight trim power, left and right turns
	9750	192.1 (fwd)	155	5100	17.0	Power trimmed to 39 psi torque pressure in 1g dive, left and right turns
	10,000	199.4 (aft)	155	5200	18.0	
Dynamic stability	9950	199.4 (aft)	62	5000	18.0	Level flight
						Climb and descent
Takeoff engine response	10,100	199.5 (aft)	Zero	2200	24.0	Takeoff to IGE[2] hover
Engine acceleration	10,000	199.4 (aft)	63	5000	16.0	Entry from descent
Engine deceleration	9950	199.4 (aft)	62	5000	16.0	Entry from climb
Pull-up	9800	199.3 (aft)	122	5100	17.0	Level flight
	9700	192.1 (fwd)				
Pushover	9800	199.3 (aft)	121	5100	17.0	Level flight
	9700	192.1 (fwd)	122			
Flare	9950	199.3 (aft)	62	2000	23.0	Maneuver complete at OGE[3] hover

[1]All tests, with the exception of dynamic stability, were conducted with SCAS ON.
[2]IGE: In ground effect.
[3]OGE: Out of ground effect.

TEST METHODOLOGY

6. Where possible, established flight test methods and data reduction procedures were used during this evaluation (ref 11, app A). Test methods are briefly described in applicable sections of the Results and Discussion section of this report. Flight test data were hand-recorded from sensitive calibrated cockpit instrumentation and were automatically recorded by two oscillographs mounted in the ammunition bay of the test helicopter. A detailed listing of the test instrumentation is contained in appendix B. A Handling Qualities Rating Scale (HQRS), as shown in the APE report, was used to augment pilot comments relative to handling qualities.

RESULTS AND DISCUSSION

GENERAL

7. Follow-on handling qualities testing of the YAH-1R helicopter was conducted to further investigate problem areas determined by the APE of the YAH-1R and to complete certain tests deleted from the YAH-1S A&FC testing due to inclement weather. Maneuvering stability characteristics at high airspeed and engine/rotor system acceleration and deceleration (droop) characteristics were of prime interest. The maneuvering stability test revealed results similar to those obtained in the APE. Maneuvering stability in a dive at 155 knots calibrated airspeed (KCAS) was neutral at normal load factors above approximately 1.4. This was due to loss of the stabilizing influence of the longitudinal stability and control augmentation system (SCAS) because of SCAS pitch channel saturation. Tests conducted to determine the engine/rotor system droop characteristics revealed the same qualitative results reported in the APE. The attempt to quantify these characteristics met with limited success due to installed instrumentation limitations and undefined flight test and data analysis techniques. The proposed increase of the engine output shaft speed limit to 6900 rpm for 10 seconds independent of power will greatly reduce pilot workload in performing deceleration maneuvers. However, the engine/rotor speed increase characteristics during these maneuvers were unaltered and remain a shortcoming in the YAH-1R helicopter. No additional deficiencies or shortcomings were found. The conclusions reached in the APE were unaltered by the results of these follow-on tests.

HANDLING QUALITIES

Collective-Fixed Static Longitudinal Stability

8. Collective-fixed static longitudinal stability was evaluated at the conditions listed in table 1. The helicopter was trimmed in diving flight at 39 psi torque pressure, zero sideslip, and 155 KCAS. Then, with the collective control held fixed, the helicopter was stabilized at incremental airspeeds greater than and less than the trim airspeed. Data were recorded at each stabilized airspeed. Test results are presented in figure 1, appendix C.

9. The effect of longitudinal cg position on the collective-fixed static longitudinal stability was determined by a comparison of figure 1, appendix C, and figure 9, reference 2, appendix A. As indicated by the variation of longitudinal cyclic control position with airspeed, the aircraft was more stable at the forward cg than at the aft cg. The further aft position of the longitudinal cyclic control, as depicted in figure 1, appendix C, when compared with figure 9 of the APE report, was caused by the forward cg location. No handling qualities difficulties were

encountered. Aircraft longitudinal control was good during simulated diving target attacks (HQRS 2). Within the scope of this test, the collective-fixed static longitudinal stability of the YAH-1R helicopter, as indicated by the variation of longitudinal cyclic control position with airspeed, is satisfactory.

Static Lateral-Directional Stability

10. Static lateral-directional stability characteristics were determined at the conditions shown in table 1. The aircraft was initially trimmed in zero sideslip flight in a dive at 155 KCAS. With the collective control fixed and airspeed held constant, the aircraft was stabilized at incremental sideslip angles both left and right from zero to the limit of the sideslip envelope. Test results are presented in figure 2, appendix C.

11. The effect of cg position on the directional stability of the YAH-1R may be seen by comparing figure 2, appendix C, and figure 12 of the APE report (app E). The forward cg position resulted in a slight increase in directional stability as indicated by the variation of directional control position with sideslip angle. Dihedral effect, as indicated by the variation of lateral cyclic control position with sideslip angle, was slightly reduced at the forward cg position but remained positive (lateral control displacement in the direction of sideslip). Side-force characteristics, as indicated by the variation of bank angle with sideslip angle, were unaffected by longitudinal cg position. Side forces were relatively weak but were sufficiently recognizable to allow the pilot to keep within the sideslip envelope during a 155-KCAS dive. Within the scope of this test, the static lateral-directional stability of the YAH-1R helicopter in a high-speed dive is satisfactory.

Dynamic Stability

12. The dynamic stability investigation conducted during this evaluation was limited to investigation of the combined effects of power and vertical speed on the fully coupled dynamic response characteristics of the YAH-1R helicopter at best-climb airspeed with SCAS OFF. Test conditions are listed in table 1. The aircraft was trimmed for zero sideslip flight at the desired power setting. The dynamic response was excited by pulse inputs of left lateral cyclic control and all controls were held fixed at the trim positions as the aircraft responded through a coupled lateral-directional and longitudinal oscillation. Lateral-directional response characteristics are presented in table 2.

Table 2. Lateral-Directional Dynamic Response Characteristics.[1] (Free Response)

Torque Setting (psi)	Damping Ratio	Period (sec)	Vertical Rate[2] (ft/min)
[3]10	Deadbeat	---	1125 Descent
16	0.54	5.1	730 Descent
23	0.1	5.6	265 Descent
27	0.04	5.0	Zero Level
38	0.0	5.1	730 Climb
43	0.0	4.9	1060 Climb
48	-0.01	4.8	1390 Climb
50	Note[4]	---	1520 Climb

[1]All tests conducted with SCAS OFF and average main rotor speed of 324 rpm.
[2]Vertical rates corrected to 10,000 pounds gross weight.
[3]Also torques below 10 psi.
[4]No quantitative values of period or damping were determined due to the highly coupled nature of the oscillation.

13. The aircraft responded primarily through the lateral-directional mode, becoming more highly coupled into the longitudinal mode as power increased above 45 psi torque pressure. The damping ratios presented in table 2 are for the lateral-directional mode. Coupling precluded an accurate computation of damping ratio for the longitudinal mode. The damping of the lateral-directional oscillation was neutral between 38 and 43 psi torque pressure. At the level flight trim point, 27 psi torque pressure, the oscillation was lightly damped. At power settings below the power required for level flight, a marked increase in damping was observed with aircraft motion becoming approximately deadbeat below 16 psi torque pressure. At power settings above 43 psi torque pressure, damping was decreased and at 48 psi torque pressure the oscillation was mildly divergent with a damping ratio of about -0.01. At power settings above 48 psi torque pressure the oscillatory divergence became increasingly rapid with increasing power. At 50 psi torque pressure, the aircraft was highly coupled in pitch and roll. It diverged in pitch during the first pitch cycle and diverged in roll during the third roll cycle. At limit power of 1290 shp (54.7 psi torque pressure in this aircraft), the coupled aircraft dynamics were aperiodically divergent in roll and pitch. Within the scope of this test, it was not possible to determine the extent to which power and vertical velocity influenced the degradation of SCAS OFF dynamic stability. The possibility exists that the divergence may be a function of rate of climb rather than power. Until the separate effects of power and rate of climb are identified, SCAS OFF flight limitations due to helicopter dynamics should be based on rate of climb. This method of limitation will assure that a light gross weight helicopter is operated with a power margin below the power settings shown in table 2. Further testing should be undertaken, using a fully instrumented AH-1G aircraft, to define the separate contributions of power and rate of climb to the degraded dynamic stability of the YAH-1R helicopter.

14. Visual flight testing indicates that SCAS OFF climbs at power settings above 38 psi torque pressure or climb rates in excess of 850 feet per minute may result in control difficulty under instrument flight conditions or in limited visibility conditions. Should control difficulty be experienced under these conditions, a reduction of power will aid in reestablishing trimmed constant-attitude flight conditions. The following NOTE should be incorporated in the operator's manual:

NOTE

> During SCAS OFF climbing flight the helicopter may develop a lateral-directional oscillation which becomes divergent with increasing power or increasing rate of climb. If such an oscillation causes control difficulty, a power reduction will aid the pilot in regaining trimmed constant-attitude flight.

Maneuvering Stability

15. Maneuvering stability characteristics were evaluated at the conditions shown in table 1 with SCAS ON. Initial trim conditions were 155 KCAS at 39 psi torque pressure and zero sideslip in 1.0g diving flight, and 60 KCAS at 27 psi torque pressure and zero sideslip in level flight. The variation of longitudinal, lateral, and directional control positions with cg normal acceleration was determined by stabilizing the aircraft in constant-airspeed zero sideslip turns at incremental bank angles left and right. The collective control remained fixed during the maneuver and power and rotor speed varied as a function of normal load factor and altitude during the descent. The quantitative results of the maneuvering stability evaluation are presented in figures 3 through 5, appendix C.

16. Figure 3, appendix C, presents the results of the maneuvering stability test initiated from trimmed level flight at 60 KCAS. The variation of longitudinal cyclic control position with normal load factor was similar to that observed in the APE. A comparison of data between figure 3 and figure 25 of the APE report shows a further aft trim cyclic control position due to the lower power setting used during this evaluation, and an apparent slight decrease in maneuvering stability above 1.2g. This apparent decrease in maneuvering stability was not noticeable in flight, and only minimal pilot compensation was required to accomplish constant-airspeed steeply banked turns initiated from level flight (HQRS 3). As in the APE, maneuvering stability tests were terminated due to high vibration levels at 1.64g.

17. Maneuvering stability test results from the YAH-1R APE indicated stable maneuvering stability throughout the load factor range tested at 60 KCAS and a neutral maneuvering stability above 1.35g at the maximum airspeed for level flight (V_H) (120 KCAS). It was recommended that further testing be accomplished to evaluate the YAH-1R maneuvering stability at high airspeed and high density altitude to determine if the aircraft becomes unstable at airspeeds above 120 KCAS. Maneuvering stability was evaluated during these tests at 155 KCAS in diving flight. Trim power for the diving flight maneuvering test was 39 psi torque pressure, the limit dive torque. Test results are presented in figures 4 and 5, appendix C. The maneuvering stability of the YAH-1R in diving flight at 155 KCAS was stable (aft control position required to maintain increased load factor) up to 1.4g. Above 1.4g, the normal acceleration at which the longitudinal SCAS actuator reached full extension at 155 KCAS, the maneuvering stability was neutral. At a load factor of 1.4 and below, only minimal pilot compensation was required for satisfactory accomplishment of simulated diving target attacks which included target changes (HQRS 3). Maneuvering flight above 1.4g was more difficult due to lack of aircraft stability, which degraded the pilot's ability to control the aircraft turn rate. Maneuvering stability tests were terminated at 1.56g (forward longitudinal cg configuration) due to high vibration levels and at 1.71g (aft longitudinal cg location) due to engine overspeed characteristics.

Tail Rotor Overtorque

18. One significant improvement in the YAH-1R when compared to the AH-1G and Q models was the increased directional control. During weapons firing tests conducted on the YAH-1S, an internal quill assembly (BHC part no. 212-040-202-1), which provides power to the tail rotor drive quill, the hydraulic pumps and transmission oil pump, failed in a hover. This failure prompted AVSCOM to request all available data concerning tail rotor overtorque conditions encountered on the YAH-1R.

19. The maximum transient tail rotor power limit of 260 shp was exceeded as defined below:

Turn reversals - Two instances - 0.45 second total

Pedal step input - Two instances - 1.3 seconds total

Acceleration - One instance - 0.1 second

Approach in critical azimuth winds - One instance - 0.15 second

Total - Six instances - 2.0 seconds total

20. The duration of the longest transient overtorque event was 0.9 second during a left directional control step input during controllability testing. Peak tail rotor power reached during the controllability tests was 310 shp (119 percent of the transient torque limit). The estimated potential for tail rotor torque is 400 shp (150 percent) following a 2-inch left directional control step input (input to the directional control mechanical stop) in a hover.

21. Inspection of the 42- and 90-degree gearboxes, tail rotor drive, and output quill revealed no indication of damage caused by the high transient tail rotor torque. The potential exists for tail rotor drive train overtorque conditions to be reached within the normal flight envelope of the YAH-1R (hover turn reversals, right lateral acceleration, etc). Further testing should be conducted with emphasis on high tail rotor power maneuvers to determine possible restrictions to the YAH-1R flight envelope.

Engine/Rotor Droop Characteristics

Background:

22. During the YAH-1R APE it was found that the coupled engine/rotor static and dynamic droop led to frequent instances of engine overspeed (engine output shaft speed greater than 6640 rpm). This overspeed condition was reached most often in quick-stop maneuvers and in turns at load factors greater than 1.4. Although this characteristic is evident in the AH-1G, the low-speed, low-altitude maneuvering requirements of the ICAM aircraft placed increased emphasis on agility

maneuvers. These maneuvers made the engine/rotor system overspeed characteristics more critical, since control of engine speed required excessive pilot attention. These engine/rotor overspeed characteristics were defined as a shortcoming during the APE and many recommendations were made concerning possible methods of rectifying this shortcoming.

General:

23. The purpose of this test was to investigate the engine/rotor acceleration and deceleration characteristics which led to the poor static and dynamic droop characteristics in engine and rotor speed. General test conditions for this evaluation are listed in table 1. Test techniques were nonstandard and were developed on-site in response to requirements stated in reference 4, appendix A. The test techniques employed will be discussed under the applicable subheadings to follow. Data analysis was undertaken on an experimental basis. It was not known what factors would affect engine/rotor droop characteristics or what parameters would produce data from which trends could be determined. Data analysis was further hampered by aircraft instrumentation which was not well-suited to this type of investigation. The data and time histories presented in figures 6 through 18, appendix C, are intended to show trends and effects only. Quantitative data will be improved in the future only by more accurate instrumentation and more refined test techniques.

24. No changes in the engine/rotor system were made subsequent to the APE. Therefore, the conclusions reached in the APE are still valid. Engine/rotor static droop was good (2 to 3 main rotor rpm) for power increases during takeoff to an IGE hover and during aircraft acceleration from airspeed for minimum power required ($V_{min\ pwr}$) to V_H, and for power decreases from IGE hover to $V_{min\ pwr}$. Engine/rotor static droop was poor during large power decreases from takeoff power to minimum power (minimum power was limited by engine overspeed tendency and was normally about 10 psi torque pressure). For this test, the droop cam was rigged to approximately 60 percent of the maximum available compensation. The poor engine/rotor static droop characteristics as a result of large power decreases remains a shortcoming in the YAH-1R helicopter. The extent of the engine overspeed tendency during large power reduction precludes safe conduct of engine testing as defined in reference 4, appendix A. The discussion which follows under various subheadings is intended to aid engineering personnel in determining the cause/effect relationship during engine response testing. Many of the maneuvers discussed have little or no bearing on operational employment of the YAH-1R; therefore, no shortcomings or deficiencies will be determined based on these tests.

Takeoff to Hover

25. The engine/rotor response characteristics during takeoff to an IGE hover were evaluated by trimming the rotor speed to 324 rpm with the aircraft on the ground and the collective control on the down stop. A normal takeoff to a stabilized 2-foot hover was accomplished and the hover collective position was noted. The aircraft was landed and several takeoffs were accomplished by pulling the collective

pitch control to the predetermined hover position at increasing collective input rates. Rotor speed was reset to 324 rpm while at minimum collective pitch prior to each takeoff.

26. As was observed in the APE, static droop characteristics were good during power increases to establish an IGE hover. Static rotor speed decreases of only 2 to 3 rpm were noted. Engine dynamic response characteristics were found to be a function of both the rate of collective control input and the shape of the input. Figure A is included to aid the reader in visualizing various input shapes. Maximum transient rotor speed decrease during these tests was 17 rpm. Figure 6, appendix C, shows that both the engine torque overshoot and the peak dynamic change in rotor speed were functions of the collective control input rate.

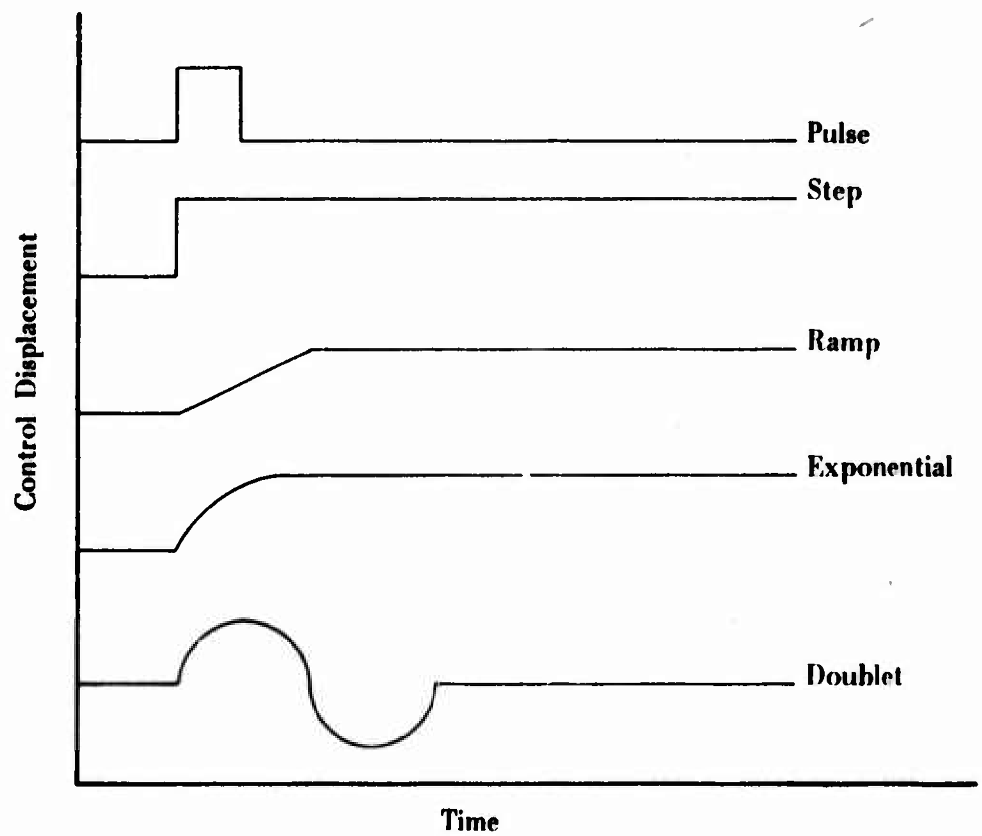


Figure A. Control Input Shapes.

27. Figures 7 and 8, appendix C, are time histories of jump takeoffs. In figure 7, the collective input was approximately exponential. The engine was able to follow this type input with no torque overshoot. The collective input shown in figure 8 had basically the same initial rate as the input shown in figure 7; however, in this case the input shape more closely approximated a ramp input. The engine response is quite different in that a peak torque overshoot occurred approximately 1.7 seconds after the input was complete.

Engine Acceleration

28. The response of the engine/rotor to in-flight power demands was evaluated at 60 knots indicated airspeed (KIAS). The basic test techniques involved trimming the engine to the static conditions desired after the control input, then moving the collective control to the initial point. The flight path was allowed to vary to achieve the engine power desired; thus, the acceleration test consisted essentially of transition from a powered descent to a maximum-power climb. The aircraft was flown in a takeoff power climb and rotor speed was trimmed to 324 rpm. Collective pitch was then lowered to the minimum possible power without exceeding the maximum engine speed limit (6784 output shaft rpm) and without using throttle or governor beep control. Interstage turbine temperature was monitored to allow the pilot to maintain engine temperatures less than the 760°C limit at this engine speed. From the low power condition, which was normally about 10 psi torque pressure, collective control was applied at varying rates to the trimmed takeoff power position.

29. As shown in figure 9, appendix C, engine torque overshoot was a function of collective application rate. The engine torque pressure rate of increase was essentially a linear function of collective rate up to a maximum rate of approximately 20 psi per second at a collective control input rate of 1.6 to 1.7 inches per second. The 20-psi-per-second torque pressure rate is apparently the maximum rate at which torque may be delivered to the rotor system. For example, during the recovery phase of a quick-stop maneuver starting with near-zero power and followed by a rapid torque demand, 2 to 3 seconds may elapse between the power demand and delivery of the demanded power. During this time interval the aircraft is underpowered. This effect causes a rate of descent to be established which in turn requires more than hover power to arrest the descent. The result is a power deficiency condition conducive to settling. Maneuvers requiring large power demands over a period of time on the order of 1 second or less will be critical due to this power deficiency. The quick-stop maneuvers such as the lateral deceleration described in the APE are prime examples of settling as a result of power deficiency induced by engine lag and acceleration characteristics.

30. Figure 10, appendix C, is a time history of a low power to maximum power input. Engine torque overshoot was minimized by an exponential-type collective input. Rotor speed evidenced some dynamic droop but again static droop in the increasing power case was negligible.

Engine Deceleration

31. Engine deceleration characteristics were evaluated in flight at 60 KIAS. The basic concept of this test was to rapidly change the power applied to the aircraft from takeoff power to zero power and observe the engine/rotor response. The flight path was allowed to vary while achieving these power changes; thus, the maneuver was essentially a transition from a takeoff power climb to autorotation without manipulation of throttle or governor beep control. Since engine overspeed tendency during large power reduction had been previously identified as a shortcoming, the engine was initially trimmed to the static conditions desired after the collective control input. The aircraft was flown in an autorotational descent and the engine speed was trimmed at 6600 rpm. Takeoff torque was then applied and the rotor was allowed to droop to about 300 rpm. After conditions had stabilized in the climb, the collective pitch control was lowered and engine deceleration characteristics were observed. Figure 11, appendix C, is a time history of this type of test. The large static droop may have been caused by trimming the engine to a zero power condition. In conducting takeoff tests, the engine was trimmed at flat pitch; however, the engine had to overcome the profile drag of the rotor system, which requires 7 to 8 psi torque pressure in the AH-1 series aircraft. Thus, the extremely low trim setting of the engine in this test may have influenced apparent poor engine/rotor static droop characteristics observed in engine deceleration testing.

32. Data scatter and pilot control actions to prevent engine or rotor overspeed conditions made it impossible to project a trend from the data acquired during these tests. Pilot workload during rapid power decreases was reduced due to the more liberal engine overspeed limits for this test (6784 output shaft rpm, as opposed to 6640 rpm for the APE). Subsequent to completion of this evaluation and in response to a verbal recommendation made by the test team during the formal test debriefing, the engine transient speed limit was raised to 6900 rpm for 10 seconds independent of turbine temperature, torque, or gas producer speed. This limit is more realistically in line with the engine response, and should reduce pilot workload during deceleration maneuvers. However, the engine/rotor droop characteristics have not been altered and they remain as a shortcoming as reported in the APE.

Autorotational Recovery

33. The engine/rotor dynamic response during recovery from an autorotational descent was evaluated by simultaneous throttle and collective control application to transition from autorotational flight, with the engine at flight-idle, to a maximum power climb. The trim point for this test was at takeoff power, 324 main rotor rpm. A time history of an autorotational recovery is presented in figure 12, appendix C.

34. The simultaneous collective and throttle control application allowed the power recovery to be accomplished with minimal rotor speed transients and engine torque overshoots. Recovery from autorotational descent into maximum power climb was accomplished with minimal pilot compensation (HQRS 3). Two drive train oscillations were noted: an oscillatory mode main rotor mast torque increase which was transmitted intermittently to the engine torque sensing element, and a sharp spike effect in the tail rotor torque. The spiking of the tail rotor torque is apparently associated with the matching of the engine and rotor speed, the point at which engine power is again delivered to the rotor system (clutch engagement). The rate of application of collective control and throttle, the phasing of collective and throttle inputs, and the aircraft attitude change or lack of change all have major effects on quantitative data. These variables are not precisely controllable by the pilot. Although the autorotational recovery maneuver should be tested to assure operational safety and acceptable aircraft handling qualities, the maneuver is not suited to obtaining repeatable engineering data for engine/rotor droop characteristics.

Pull-Ups and Pushovers

35. The engine/rotor characteristics were evaluated during pull-up and pushover maneuvers at the conditions listed in table 1. Time histories are presented in figures 13 and 14, appendix C. Negligible effects on rotor speed were detected. Engine torque was affected by both pull-up and pushover maneuvers. The torque decrease during the pull-up was due primarily to the increased load factor. A slight increase in rotor speed was associated with the torque decrease. Although this increase in rotor speed was noted by the pilot, the phenomenon was familiar and recognizable as a transient condition requiring no pilot compensation. The rotor speed increase due to normal load factor generated on a short-term basis during pull-up and pushover maneuvers was negligible when compared to sustained load factors.

Longitudinal Flare Deceleration Maneuvers

36. The effects of a rapid longitudinal flare maneuver (quick stop) on the engine/rotor system dynamics were evaluated at the conditions listed in table 1. These maneuvers were performed as constant-altitude quick stops from an initial airspeed of 62 KCAS. Since one constraint of this maneuver was maintaining constant altitude, the pitch rate and maximum pitch attitude used for this maneuver determined the rate of collective control decrease. The deceleration flares were accomplished in two ways. The one method involved deceleration at a constant maximum pitch attitude achieved at a nominal slow pitch rate. Data are presented in figures 15 and 16, appendix C. The second method involved varying the pitch rate to a predetermined decelerating pitch attitude. Data are presented in figures 17 and 18. To avoid engine overspeed during tests at the higher flare rate and attitudes, the engine was trimmed to 6400 rpm engine output shaft speed. Both the pitch attitude and the rate at which that attitude was achieved affected the amount of torque decrease required to maintain level flight during the deceleration. The increase in rotor speed was an essentially linear function of both pitch rate and

pitch attitude. As may be seen from figures 15 and 17, the maximum change in rotor speed during the flare maneuvers was approximately 12 rpm; therefore, from a normal trim condition of 324 rpm main rotor speed, the maximum rotor speed reached should be 336 rpm (approximately 6844 rpm engine output shaft speed). The adoption of an engine output shaft speed limit of 6900 rpm would allow the pilot to perform these maneuvers without compensation to avoid engine overspeeds.

RECOMMENDATION FOR TEST DEVELOPMENT

37. During the conduct of this evaluation, time constraints precluded development of test techniques that would allow determination of the separate effects of various parameters on the engine/rotor system dynamics. Many diverse factors will influence test results, among them: engine trim point, rate of application of collective and throttle control, the shape of the control input, the range of control movement, aerodynamic effects on the rotor system, mechanical or aerodynamic coupling, aircraft attitude and rate, normal load factors, flight condition, change in the collective control/power relationship, droop cam profile, and droop cam rigging. Further testing is required to develop test and data analysis techniques to isolate the effects of the various parameters on engine/rotor system static and dynamic characteristics. These tests should be conducted on a fully-instrumented aircraft equipped to explore sensor response and range necessary to acquire accurate data.

CONCLUSIONS

GENERAL

38. No additional deficiencies or shortcomings were determined during this evaluation.

39. The conclusions of the APE (USAAEFA Final Report No. 74-33) are unaltered.

40. Adoption of a new engine output shaft speed limit (6900 rpm for 10 seconds independent of temperature) will greatly reduce pilot workload during deceleration maneuvers (paras 7 and 37).

41. The engine overspeed tendency of the YAH-1R helicopter precludes safe conduct of engine testing as defined in reference 4, appendix A (para 24).

42. The large number of variable parameters to be controlled by the pilot during autorotational recoveries makes the maneuver unsuited for obtaining repeatable engineering data for engine/rotor droop characteristics (para 34).

SPECIFICATION COMPLIANCE

43. Within the scope of this evaluation, the YAH-1R helicopter met all the requirements of MIL-H-8501A against which it was tested.

RECOMMENDATIONS

44. Further testing should be undertaken utilizing properly-instrumented AH-1G aircraft to define the separate contributions of power and rate of climb to the degraded dynamic stability of the YAH-1R helicopter (para 13).

45. The following NOTE should be included in the operator's manual (para 14):

NOTE

> During SCAS OFF climbing flight the helicopter may develop a lateral-directional oscillation which becomes divergent with increasing power or increasing rate of climb. If such an oscillation causes control difficulty, a power reduction will aid the pilot in regaining trimmed constant-attitude flight.

46. Further testing should be conducted with emphasis on high tail rotor power maneuvers to determine possible restrictions to the YAH-1R flight envelope (para 21).

47. Testing should be undertaken using fully-instrumented aircraft to develop flight test and data reduction techniques required to isolate the effects of various flight parameters on engine/rotor static and dynamic response. Test aircraft should be equipped to explore the sensor response and range necessary to acquire accurate data (para 37).

APPENDIX A. REFERENCES

1. Final Report, USAASTA, Project No. 74-43, *Airworthiness and Flight Characteristics Evaluation, AH-1Q Helicopter*, July 1973.

2. Final Report, USAAEFA, Project No. 74-33, *Army Preliminary Evaluation, YAH-1R Improved Cobra Agility and Maneuverability Helicopter*, May 1975.

3. Message, AVSCOM, AMSAV-EQI, 161315Z April 1975, subject: Termination of A&FC Tests.

4. Message, AVSCOM, AMSAV-EQI, 261955Z April 1975, subject: Test Conditions for Rotor Droop Evaluation of ICAM Helicopter, Project No. 74-33/34.

5. Message, AVSCOM, AMSAV-EQI, 011630Z May 1975, subject: SOFR for ICAM A&FC Evaluation, Project 74-34.

6. Technical Manual, TM 55-1520-221-10, *Operator's Manual, Army Model AH-1G Helicopter*, 19 June 1971.

7. Final Report, USAASTA, Project No. 72-30, *Engineering Flight Test, AH-1G Helicopter with Model 212 Tail Rotor, Part II, Performance and Handling Qualities*, September 1973.

8. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities; General Requirements For*, 7 September 1961, with Amendment 1, 3 April 1962.

9. Letter, AVSCOM, AMSAV-EQI, 17 March 1975, subject: Safety of Flight Release for Conduct of Airworthiness and Flight Characteristics Evaluation, YAH-1S ICAM Helicopter.

10. Technical Manual, TM 55-1520-221-10, *YAH-1R Supplement to Operator's Manual, Army Model AH-1G Helicopter*, unpublished.

11. Flight Test Manual, Naval Air Test Center, FTM No. 101, *Helicopter Stability and Control*, 10 June 1968.

APPENDIX B. INSTRUMENTATION

Instrumentation was installed in the test aircraft by BHC prior to the start of the test program. Two oscillograph recorders were located in the ammunition bay for all testing. All instrumentation was calibrated and maintained by BHC. The following parameters were recorded:

<u>Pilot Panel</u>

Airspeed (sensitive boom)
Altitude (boom)
Center-of-gravity normal acceleration
Engine torque (ship's system)
Event switch
Oscillograph operate switch
Outside air temperature
Angle of sideslip
Control position indicator:
- Lateral
- Longitudinal
- Directional
- Collective

Interstage turbine temperature
Main rotor speed (sensitive and ship's system)
Vertical speed (ship's system)

<u>Copilot/Engineer Panel</u>

Airspeed (sensitive boom and ship's system)
Altitude (boom and ship's system)
Engine torque (ship's system)
Tail rotor torque
Event switch
Oscillograph operate switch
Angle of sideslip
Sensitive outside air temperature
Vertical speed (boom)
Interstage turbine temperature

Oscillograph

Control position:
- Longitudinal
- Lateral
- Collective
- Directional

Longitudinal SCAS position
Lateral SCAS position
Directional SCAS position
Pitch attitude
Roll attitude
Yaw attitude
Pitch rate
Roll rate
Yaw rate
Center-of-gravity normal acceleration
Throttle position
Engine torque
Main rotor mast torque
Main rotor flapping angle
Main rotor linear rpm
N_2 linear rpm
N_1 linear rpm
Turbine outlet temperature
N_2 linear actuator position
Tail rotor mast torque
Tail rotor flapping angle
Main rotor/tail rotor azimuth
Tail rotor blade angle
Airspeed
Angle of attack
Angle of sideslip
Pilot/copilot event

APPENDIX C. TEST DATA

INDEX

FIGURE 1
COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY
YAH-1R USA S/N 70-15936

AVG GROSS WEIGHT ~LB	AVG CG LOCATION LONG FS	AVG CG LOCATION LAT BL	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	AVG ROTOR SPEED ~RPM	AVG C_T X10⁴	CONFIGURATION	FLIGHT CONDITION
9580	192.1(FWD)	-0.1(MID)	5500	17	324	56.01	HOG	DIVE

NOTES: 1. SHADED SYMBOLS DENOTE TRIM.
2. COLLECTIVE CONTROL POSITION = 4.0 INCHES FROM FULL DOWN
3. ANGLE OF SIDESLIP = ZERO DEGREES.
4. TRIM POWER = 900 SHP

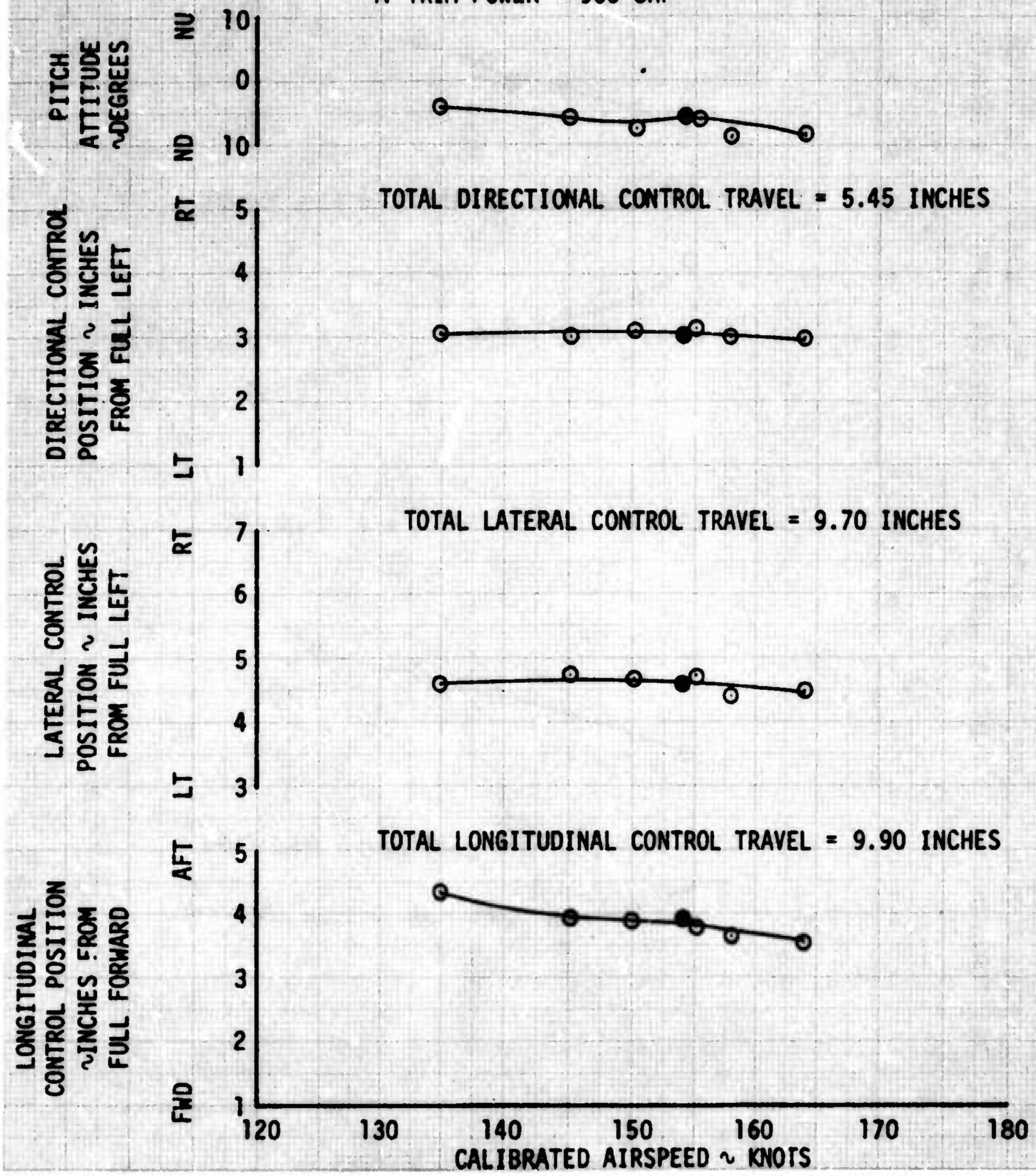


FIGURE 2

STATIC LATERAL DIRECTIONAL STABILITY

YAH-1R USA S/N 70-15936

AVG GROSS WEIGHT ~LB	AVG CG LOCATION LONG FS	AVG CG LOCATION LAT BL	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	AVG ROTOR SPEED ~RPM	AVG C_T X10^4	TRIM A/S ~KCAS	CONFIG	FLIGHT COND
9480	192.1(FWD)	-0.1(MID)	5400	17.5	324	55.35	155	HOG	DIVE

NOTES: 1. SHADED SYMBOLS DENOTE TRIM.
2. COLLECTIVE CONTROL POSITION = 3.9 INCHES FROM FULL DOWN.
3. TRIM POWER = 900 SHP

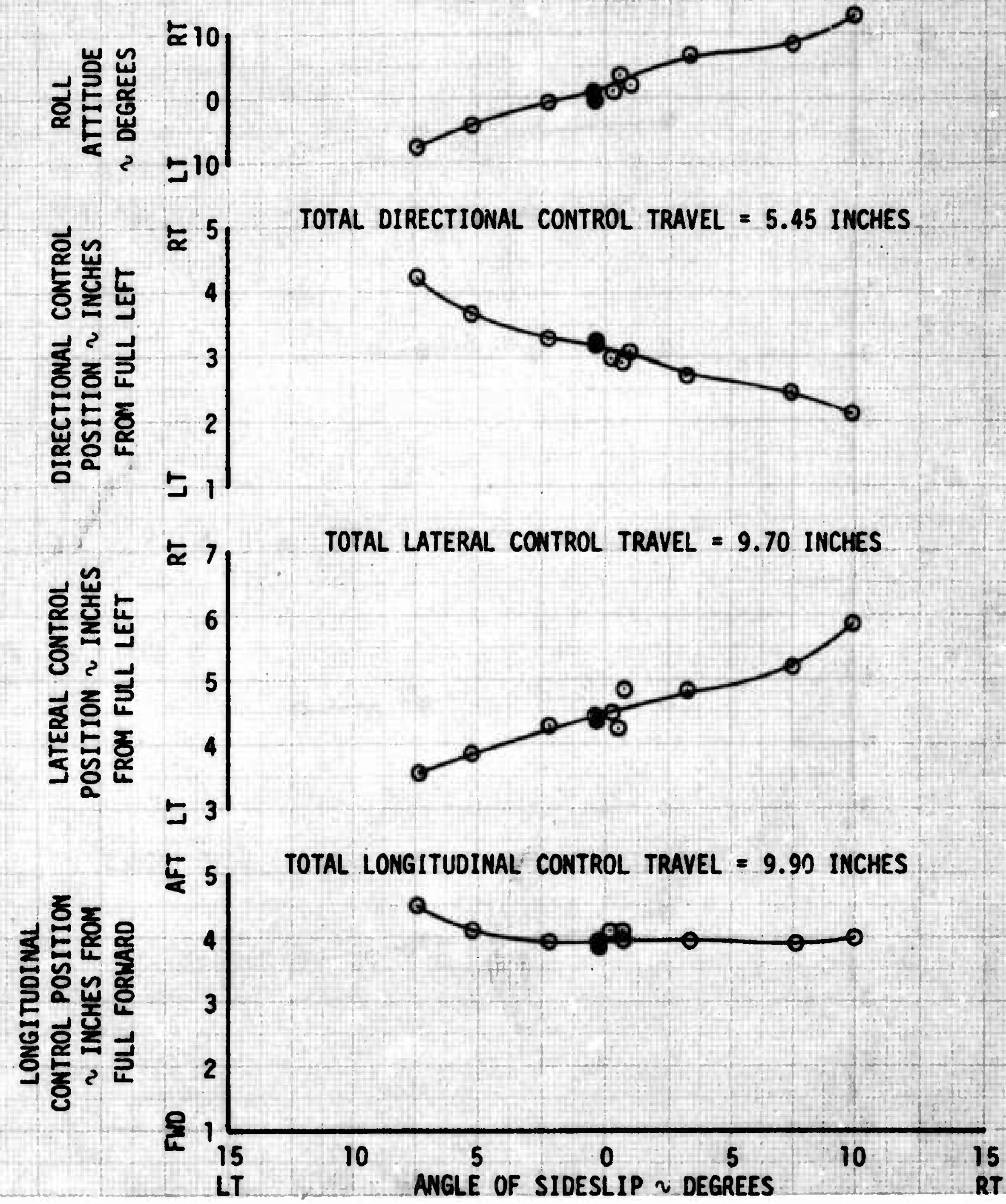


FIGURE 3
MANEUVERING STABILITY
YAH-1R USA S/N 70-15936

AVG GROSS WEIGHT ~LB	AVG CG LOCATION LONG FS	AVG CG LOCATION LAT BL	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	AVG ROTOR SPEED ~RPM	AVG C_T X10^4	TRIM A/S ~KCAS	CONFIG	FLIGHT COND
9970	199.4(AFT)	-0.1(MID)	4900	16	324	57.43	60	HOG	STDY TRNS

NOTES: 1. SOLID SYMBOLS DENOTE TRIM POINT.
2. FLAGGED SYMBOLS DENOTE LEFT TURN.
3. TRIM POWER = 590 SHP.
4. SCAS ON.
5. CONTROL FORCES DETERMINED FROM GROUND MEASUREMENTS.

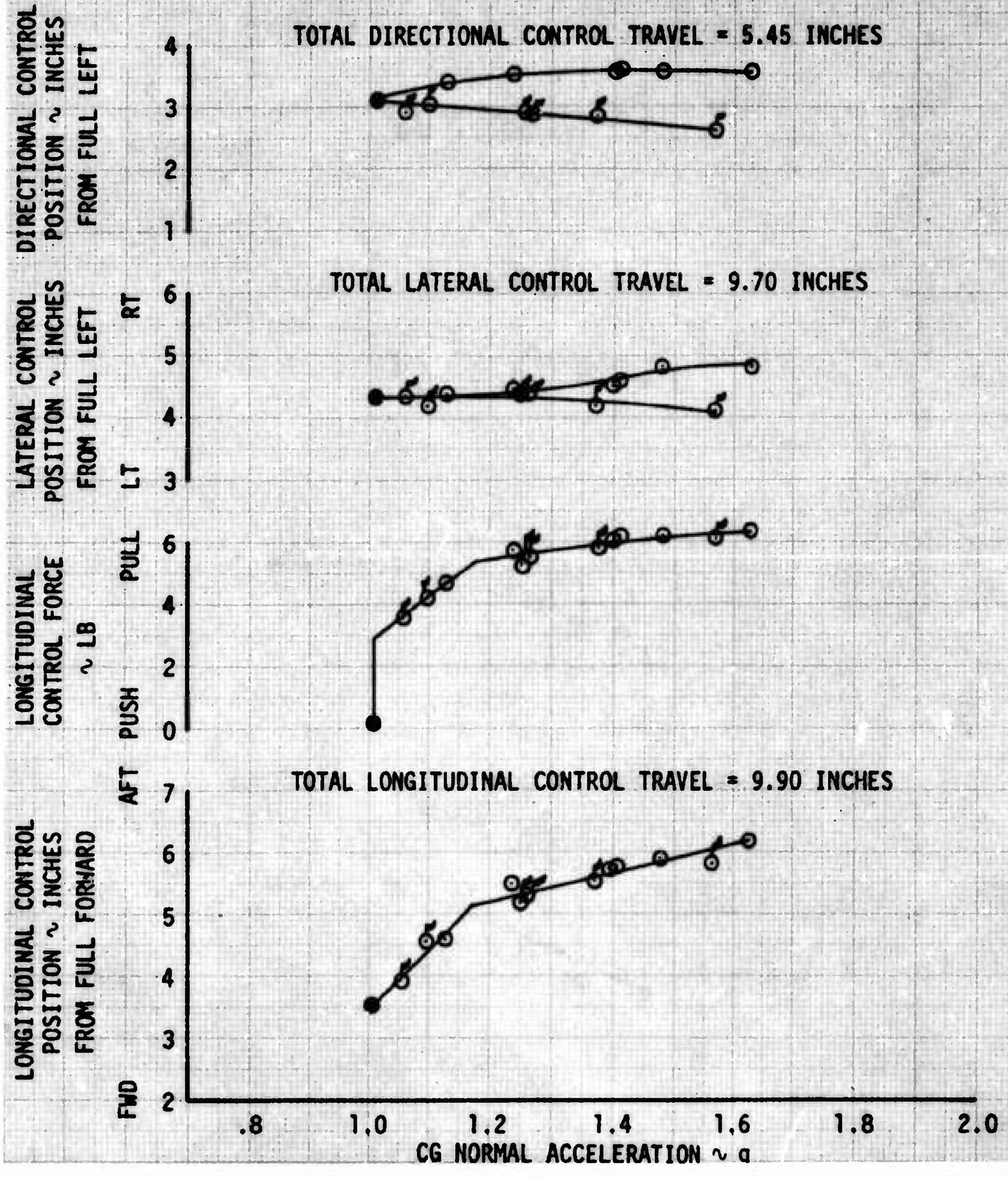


FIGURE 4
MANEUVERING STABILITY
YAH-1R USA S/N 70-15936

AVG GROSS WEIGHT ~LB	AVG CG LOCATION LONG FS	AVG CG LOCATION LAT BL	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	AVG ROTOR SPEED ~RPM	AVG C_T X10[4]	TRIM A/S ~KCAS	CONFIG	FLIGHT COND
9750	192.1(FWD)	-0.1(MID)	5100	17	324	56.37	155	HOG	STDY TRNS

NOTES:
1. SOLID SYMBOLS DENOTE TRIM POINT.
2. FLAGGED SYMBOLS DENOTE LEFT TURN.
3. TRIM POWER = 936 SHP
4. SCAS ON.
5. CONTROL FORCES DETERMINED FROM GROUND MEASUREMENTS.

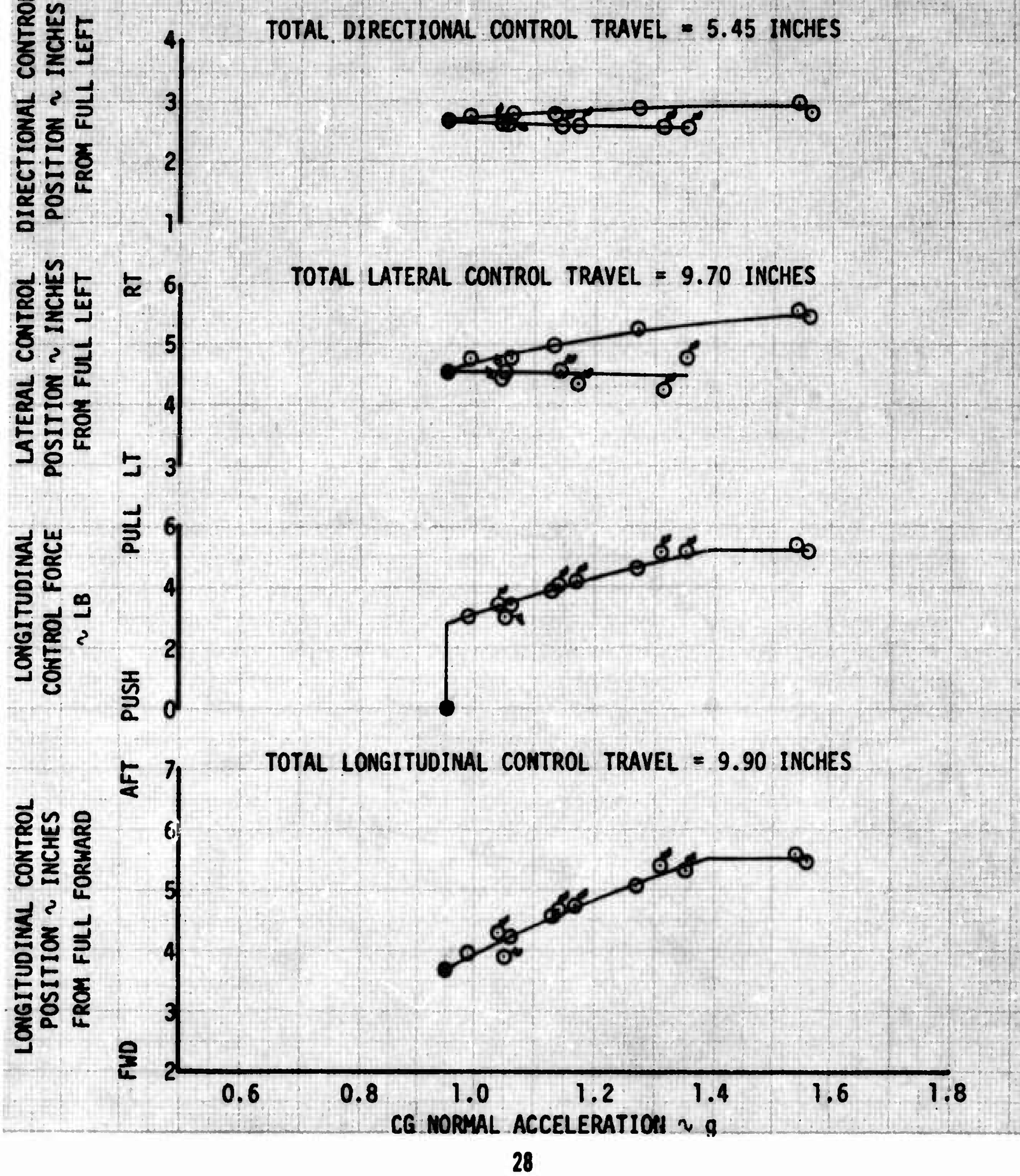


FIGURE 5
MANEUVERING STABILITY
YAH-1R USA S/N 70-15936

AVG GROSS WEIGHT ~LB	AVG CG LOCATION LONG FS	AVG CG LOCATION LAT BL MID	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	AVG ROTOR SPEED ~RPM	AVG C_T X10^4	TRIM A/S ~KCAS	CONFIG	FLIGHT COND
10000	199.4(AFT)	-0.1(LT)	5200	18	324	58.02	155	HOG	STDY TURNS

NOTES: 1. SOLID SYMBOLS DENOTE TRIM POINT.
2. FLAGGED SYMBOLS DENOTE LEFT TURN.
3. AVERAGE TRIM POWER = 938 SHP.
4. SCAS ON.
5. CONTROL FORCES DETERMINED FROM GROUND MEASUREMENTS.

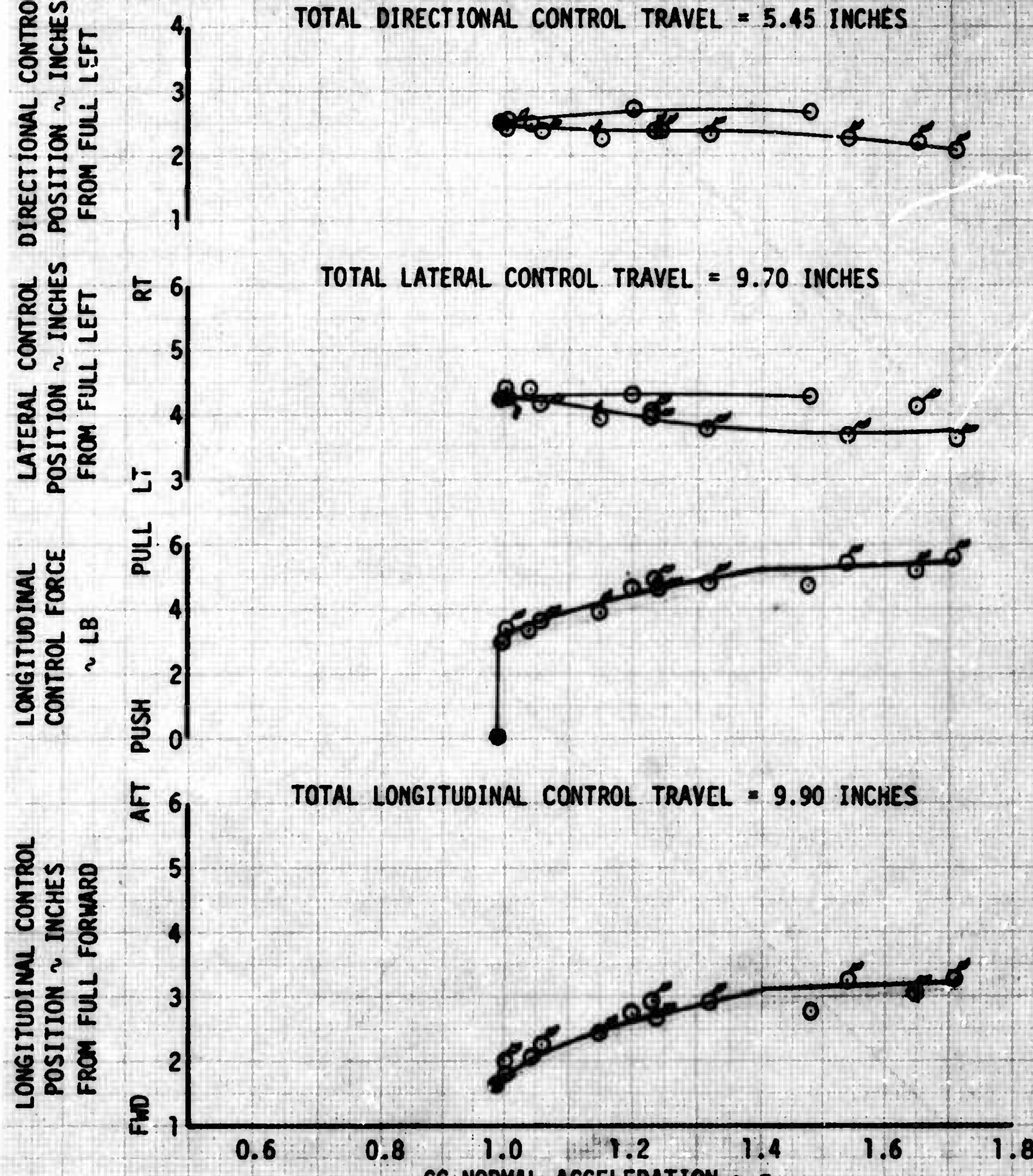


FIGURE 6
TAKEOFF ENGINE RESPONSE
YAH-1R USA S/N 70-15936

AVG GROSS WEIGHT ~LB	AVG CG LOCATION LONG FS	AVG CG LOCATION LAT BL	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	AVG ROTOR SPEED ~RPM	AVG C_T X10^4	CONFIG	FLIGHT COND
10100	199.4(AFT)	-0.1(MID)	2200	24	324	53.41	HOG	IGE HOVER

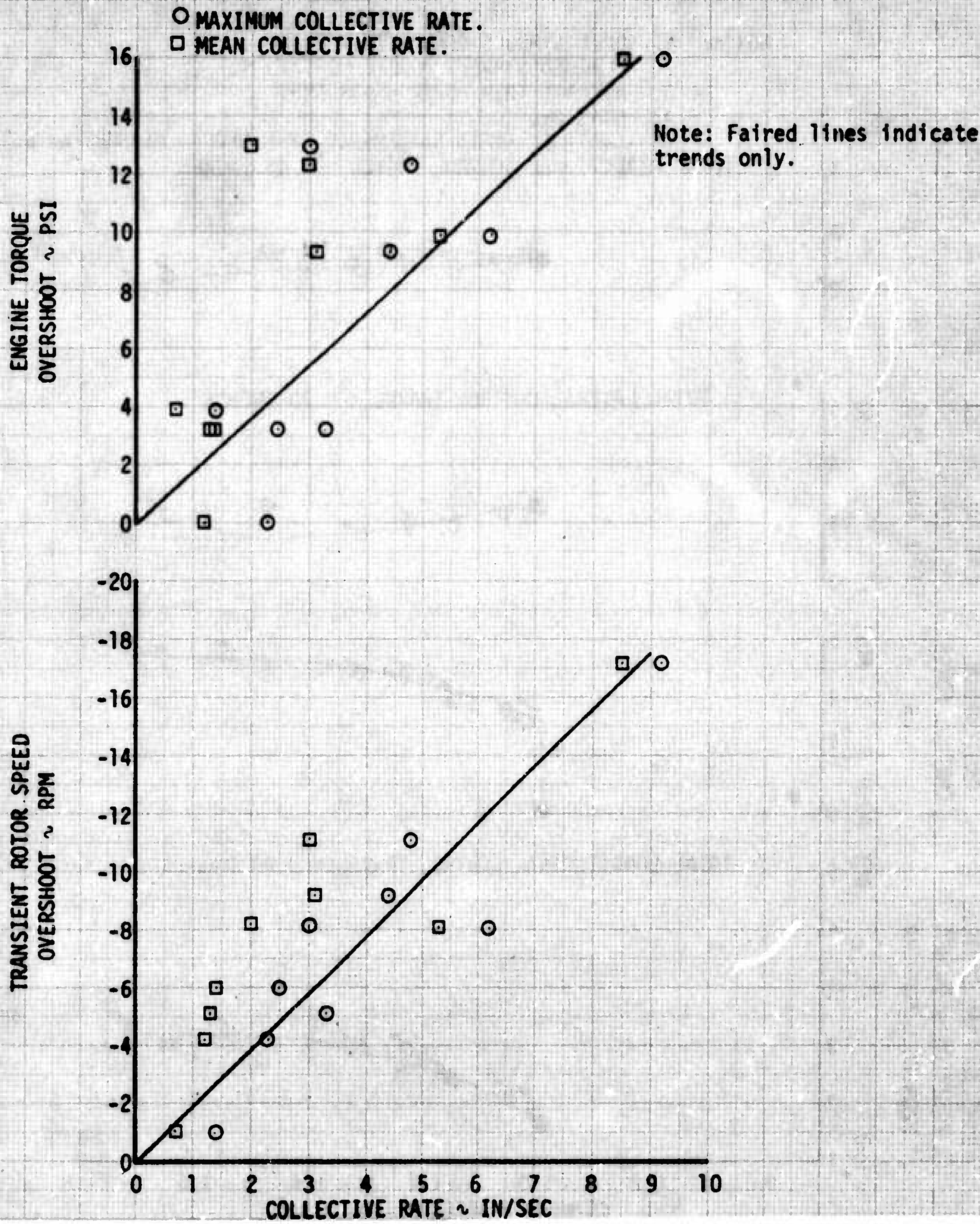


FIGURE 7
TAKEOFF TO IGE HOVER
YAH-1P USA S/N 70-15936

GROSS WEIGHT ~LB	CG LOCATION LONG FS	CG LOCATION LAT BL	DENSITY ALTITUDE ~FT	OAT ~°C	TRIM ROTOR SPEED ~RPM	C_T $\times 10^4$	CONFIGURATION
10200	199.5(AFT)	-0.1(LT)	2100	24	324	53 63	HOG

NOTE: TAIL ROTOR TORQUE IS SHOWN IN PERCENT OF THE MAXIMUM TRANSIENT VALUE (260 SHP AT 1654 RPM TAIL ROTOR SPEED).
ENGINE TORQUE IS SHOWN AS A PERCENT OF THE MAXIMUM ALLOWABLE TORQUE (1290 SHP AT 6600 RPM ENGINE OUTPUT SHAFT SPEED).

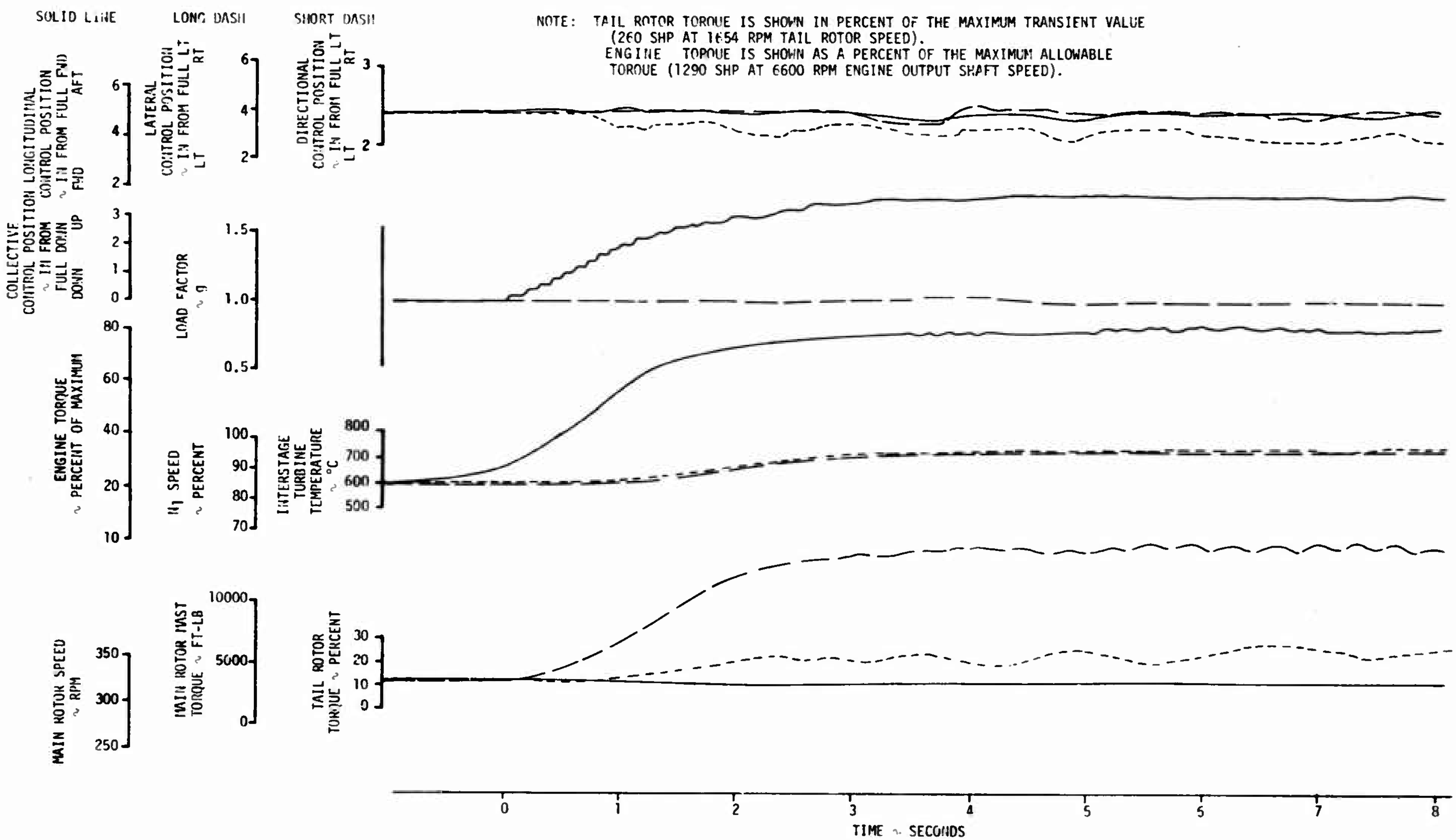


FIGURE 8
TAKEOFF TO IGE HOVER
YAH-1R USA S/N 70-15936

GROSS WEIGHT ~LB	CG LOCATION LONG FS	CG LOCATION LAT BL	DENSITY ALTITUDE ~FT	OAT ~°C	TRIM ROTOR SPEED ~RPM	C_T x10^4	CONFIGURATION
10150	199.5(AFT)	-0.1(LT)	2100	24	324	53.58	HOG

NOTE: TAIL ROTOR TORQUE IS SHOWN IN PERCENT OF THE MAXIMUM TRANSIENT VALUE (260 SHP AT 1654 RPM TAIL ROTOR SPEED).
ENGINE TORQUE IS SHOWN AS A PERCENT OF THE MAXIMUM ALLOWABLE TORQUE (1290 SHP AT 6600 RPM ENGINE OUTPUT SHAFT SPEED).

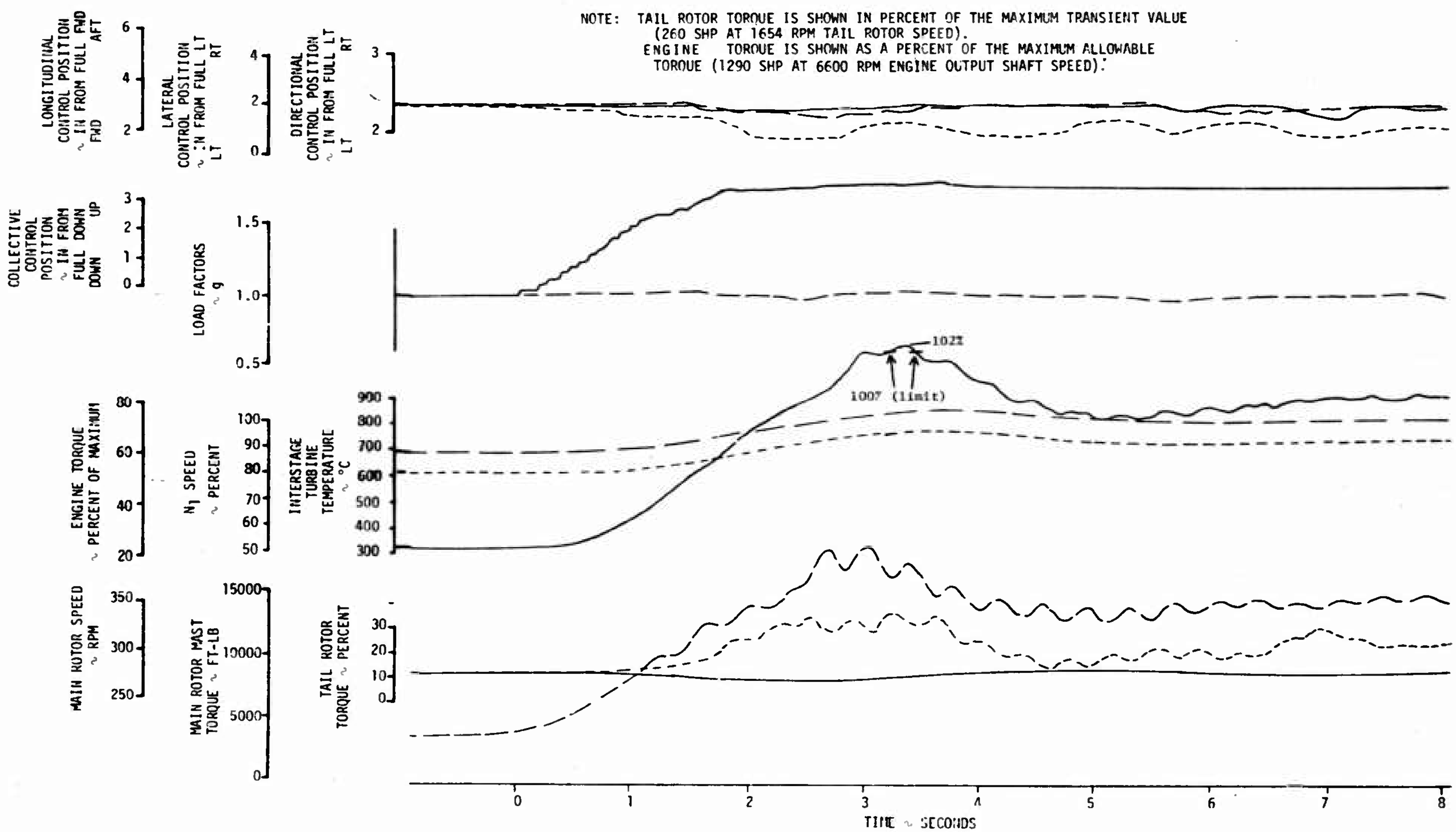


FIGURE 9
ENGINE ACCELERATION
YAH-1R USA S/N 70-15936

AVG GROSS WEIGHT ~LB	AVG CG LOCATION LONG FS	AVG CG LOCATION LAT BL	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	AVG ROTOR SPEED ~RPM	AVG C_T X10⁴	TRIM A/S ~KCAS	CONFIG
10000	199.4(AFT)	-0.1(MID)	5000	16	324	57.63	63	HOG

○ MAXIMUM COLLECTIVE RATE.
□ MEAN COLLECTIVE RATE.

NOTE: Faired lines indicate trends only.

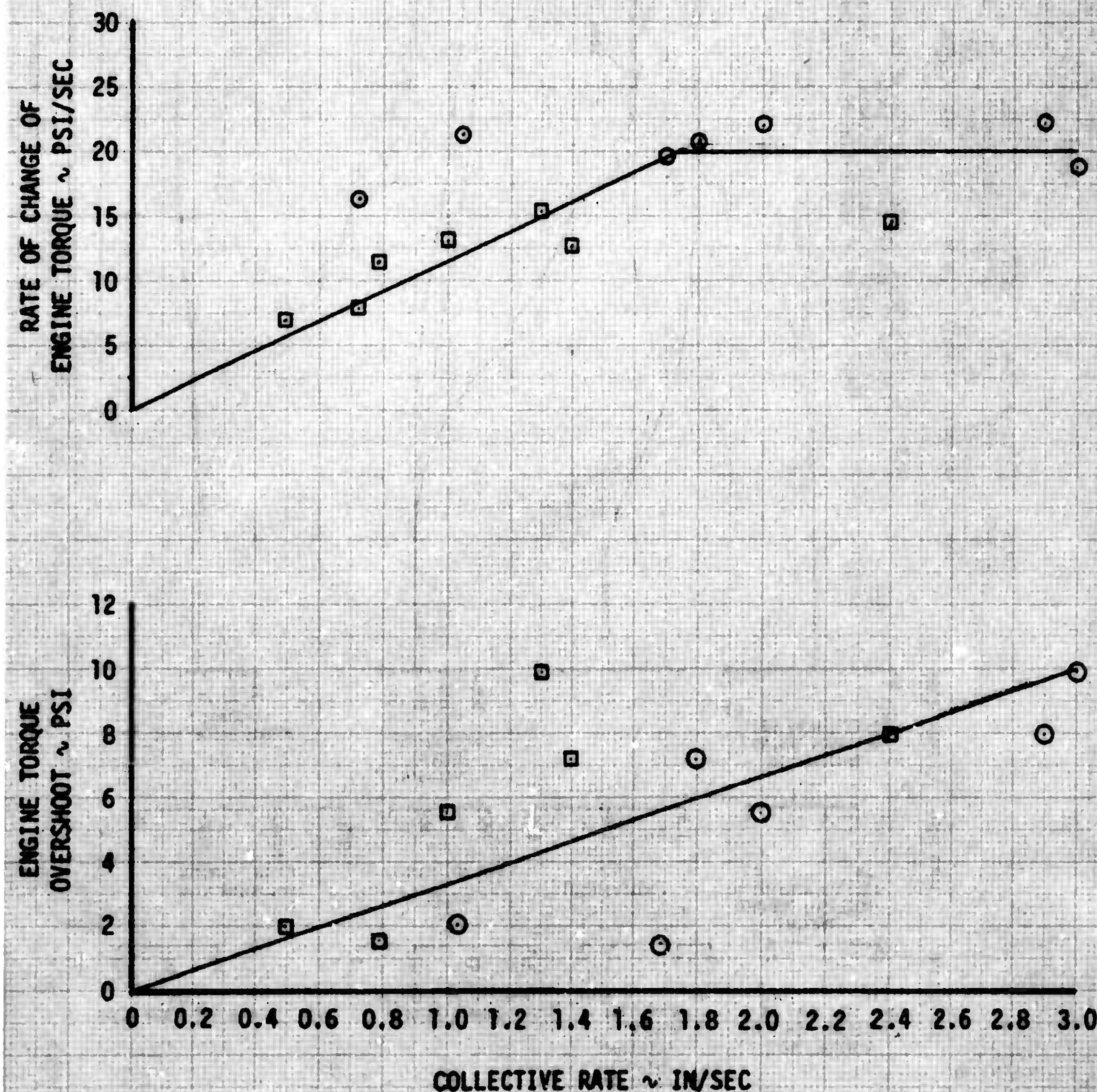


FIGURE 10
ENGINE ACCELERATION
YAH-1R USA S/N 70-15936

GROSS WEIGHT ~LB	CG LOCATION LONG FS	CG LOCATION LAT BL	DENSITY ALTITUDE ~FT	OAT ~°C	TRIM ROTOR SPEED ~RPM	C_T x10⁴	TRIM AIRSPEED ~KCAS	CONFIGURATION	FLIGHT CONDITION
9980	199.3(AFT)	-0.1(LT)	5600	18	324	58.55	64	HOG	INITIATED FROM POWERED DESCENT

NOTE: TAIL ROTOR TORQUE IS SHOWN IN PERCENT OF THE MAXIMUM TRANSIENT VALUE (260 SHP AT 1654 RPM TAIL ROTOR SPEED).
ENGINE TORQUE IS SHOWN AS A PERCENT OF THE MAXIMUM ALLOWABLE TORQUE (1290 SHP AT 6600 RPM ENGINE OUTPUT SHAFT SPEED).

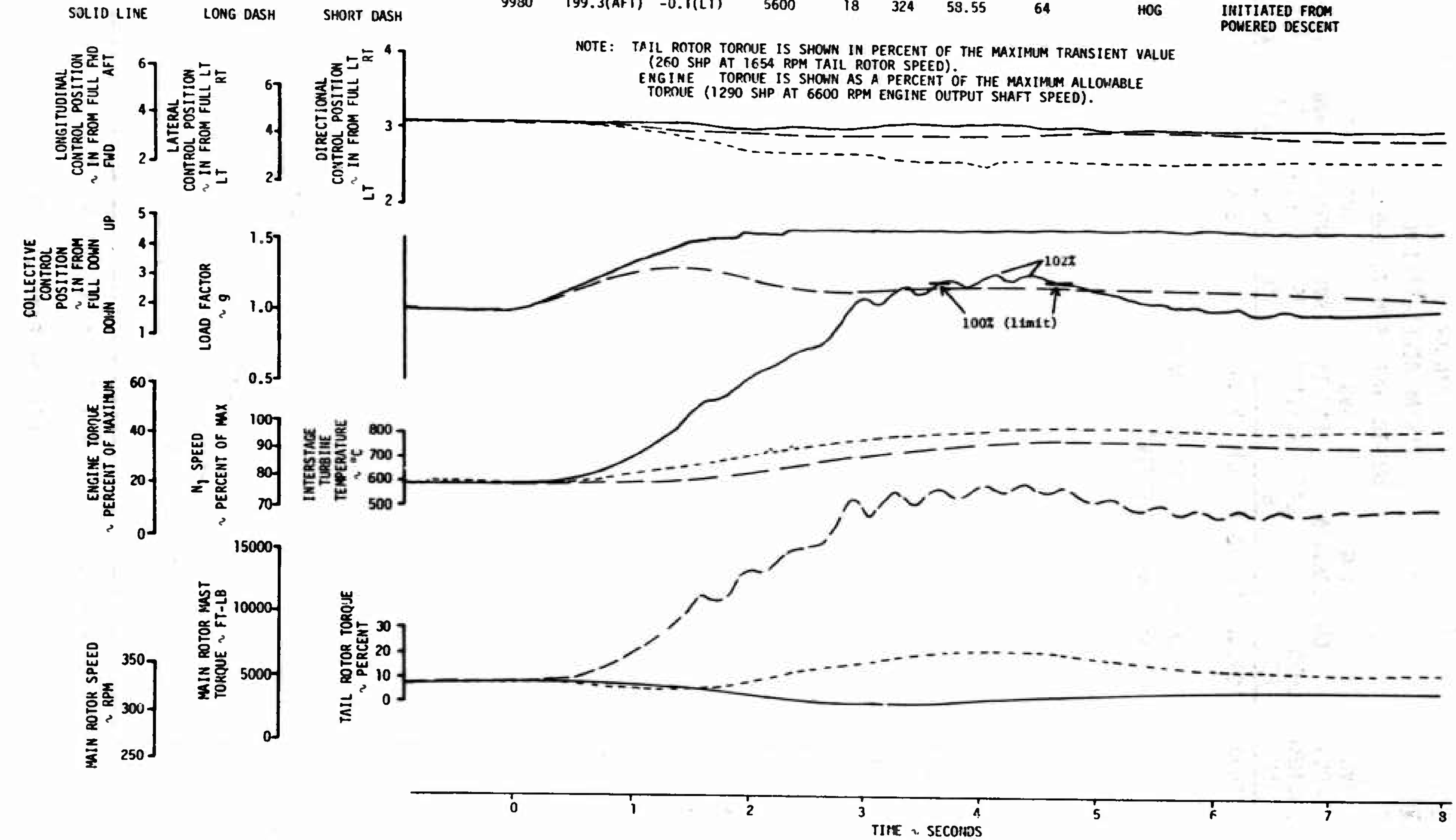


FIGURE 11
ENGINE DECELERATION
YAH-1R USA S/N 70-15936

GROSS WEIGHT ~LB	CG LOCATION LONG FS	CG LOCATION LAT BL	DENSITY ALTITUDE ~FT	OAT ~°C	TRIM ROTOR SPEED ~RPM	C_T x10^4	TRIM AIRSPEED ~KCAS	CONFIGURATION	FLIGHT CONDITION
9940	199.3(AFT)	-0.1(LT)	5400	17	324	57.97	65	HOG	INITIATED FROM MAXIMUM POWER CLIMB

NOTE: TAIL ROTOR TORQUE IS SHOWN IN PERCENT OF THE MAXIMUM TRANSIENT VALUE (260 SHP AT 1654 RPM TAIL ROTOR SPEED).
ENGINE TORQUE IS SHOWN AS A PERCENT OF THE MAXIMUM ALLOWABLE TORQUE (1290 SHP AT 6600 RPM ENGINE OUTPUT SHAFT SPEED).

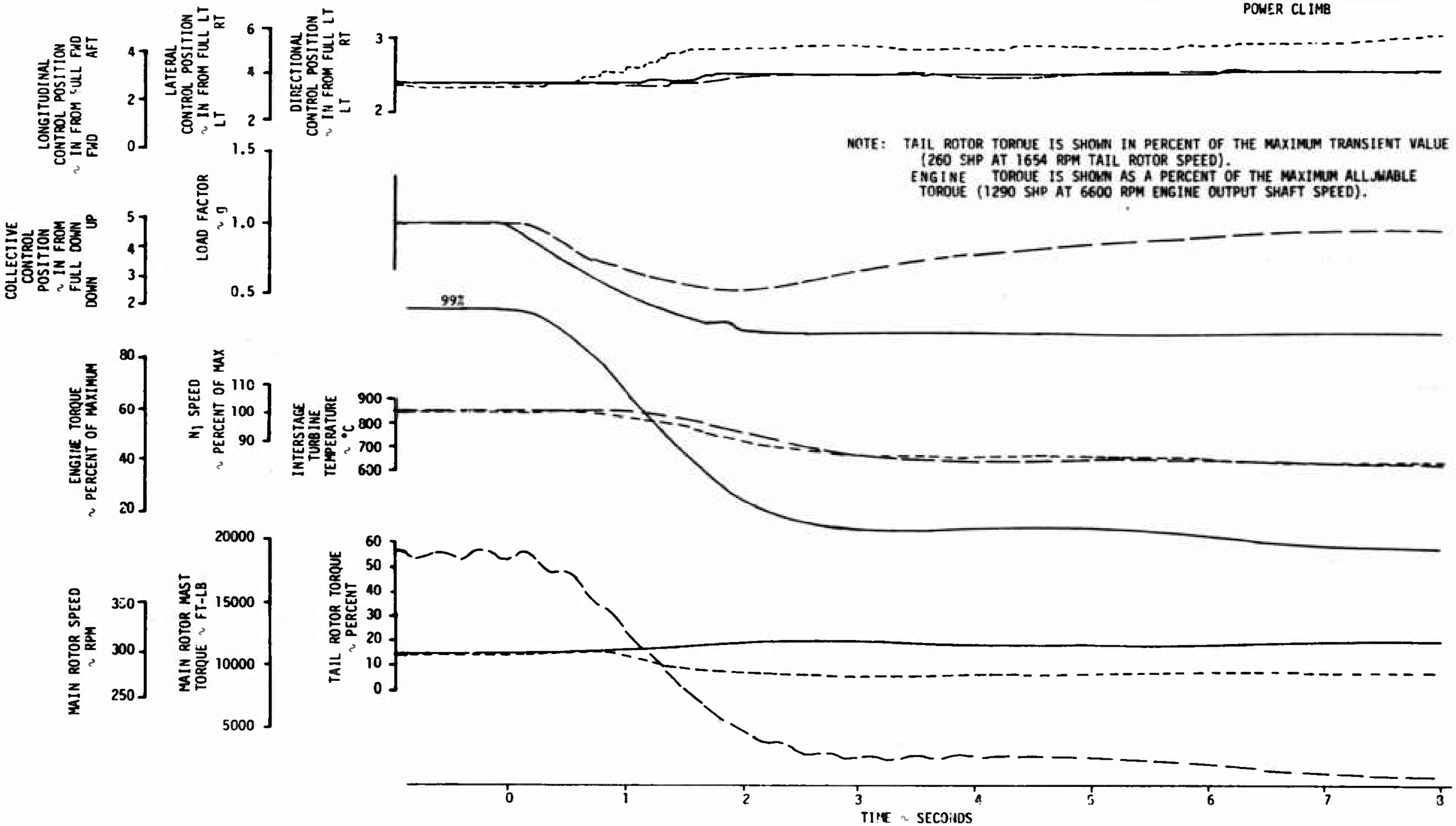


FIGURE 12
AUTOROTATIONAL RECOVERY
YAH-1R USA S/N 70-15936

GROSS WEIGHT ~LB	CG LOCATION LONG FS	CG LOCATION LAT BL	DENSITY ALTITUDE ~FT	OAT ~°C	TRIM ROTOR SPEED ~RPM	C_T x10^4	TRIM AIRSPEED ~KCAS	CONFIGURATION	TRIM FLIGHT CONDITION
9950	199.3(AFT)	-0.1(LT)	4300	15	324	56.11	64	HOG	AUTOROTATION

NOTE: TAIL ROTOR TORQUE IS SHOWN IN PERCENT OF THE MAXIMUM TRANSIENT VALUE (260 SHP AT 1654 RPM TAIL ROTOR SPEED).
ENGINE TORQUE IS SHOWN AS A PERCENT OF THE MAXIMUM ALLOWABLE TORQUE (1290 SHP AT 6600 RPM ENGINE OUTPUT SHAFT SPEED).

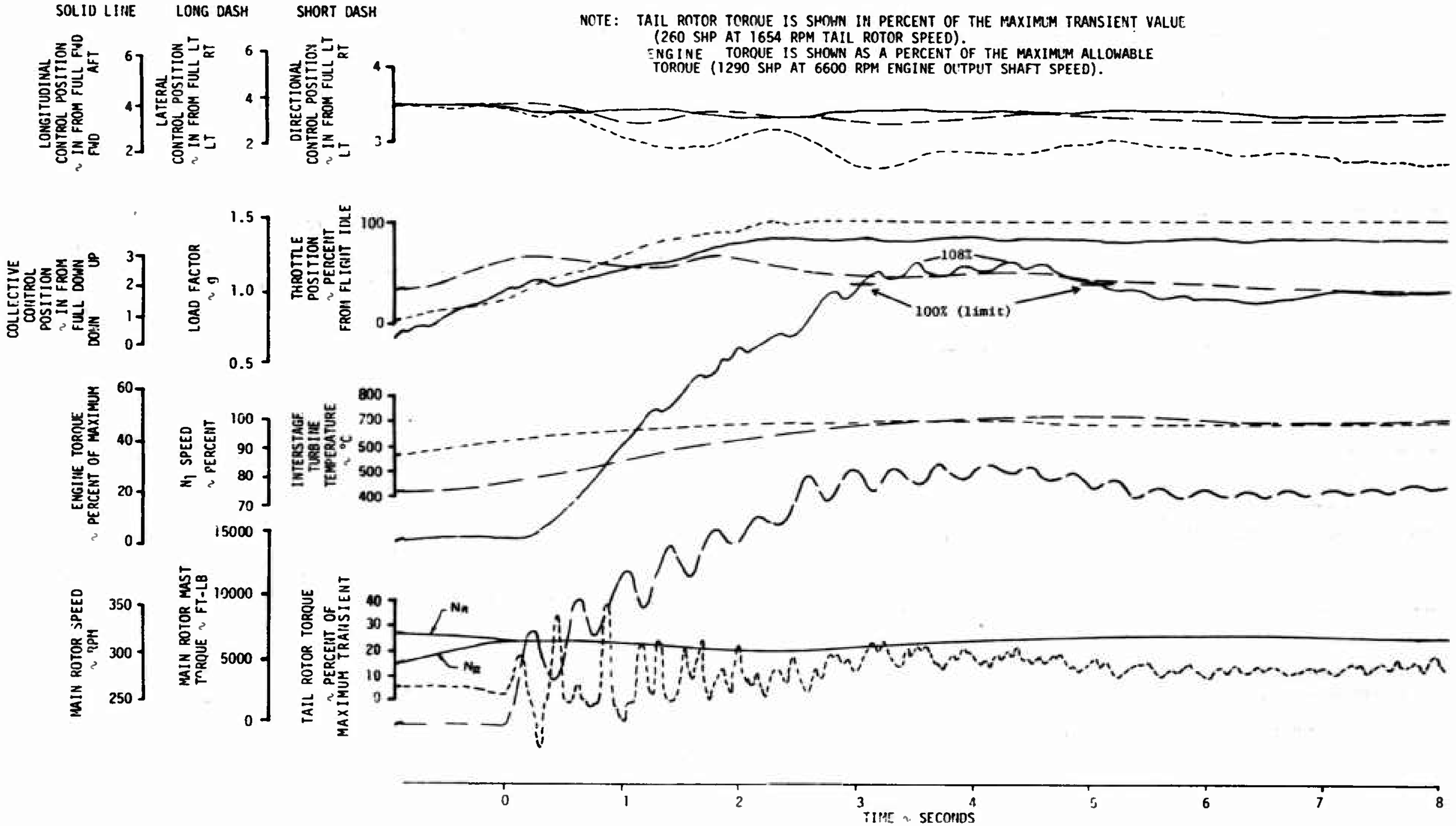


FIGURE 13
ENGINE/ROTOR CHARACTERISTICS DURING A PULLUP
YAH-1R USA S/N 70-15936

GROSS WEIGHT ~LB	CG LOCATION LONG FS	CG LOCATION LAT BL	DENSITY ALTITUDE ~FT	OAT ~°C	TRIM ROTOR SPEED ~RPM	C_T $\times 10^4$	TRIM AIRSPEED ~KCAS	CONFIGURATION	FLIGHT CONDITION
9700	191.9(FWD)	-0.1(LT)	5300	17	324	56.37	124	HOG	LEVEL FLIGHT

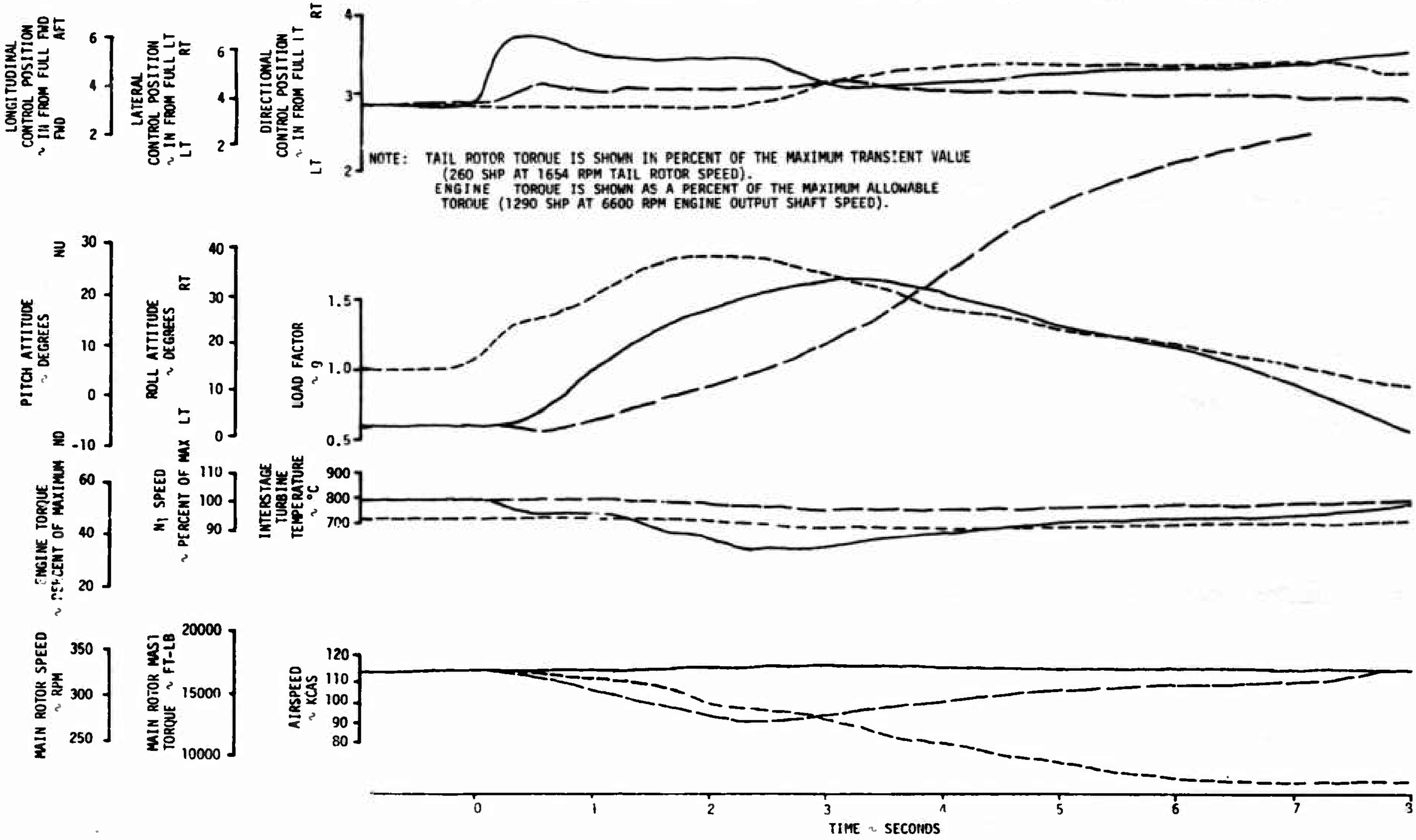


FIGURE 14
ENGINE/ROTOR CHARACTERISTICS DURING A PUSHOVER
YAH-1R USA S/N 70-15936

GROSS WEIGHT ~LB	CG LOCATION LONG FS	CG LOCATION LAT BL	DENSITY ALTITUDE ~FT	OAT ~°C	TRIM ROTOR SPEED ~RPM	C_T x10^4	TRIM AIRSPEED ~KCAS	CONFIGURATION	FLIGHT CONDITION
9730	199.3(AFT)	-0.1(LT)	5900	18	324	57.92	123	HOG	LEVEL FLIGHT

NOTE: TAIL ROTOR TORQUE IS SHOWN IN PERCENT OF THE MAXIMUM TRANSIENT VALUE (260 SHP AT 1654 RPM TAIL ROTOR SPEED).
ENGINE TORQUE IS SHOWN AS A PERCENT OF THE MAXIMUM ALLOWABLE TORQUE (1290 SHP AT 6600 RPM ENGINE OUTPUT SHAFT SPEED).

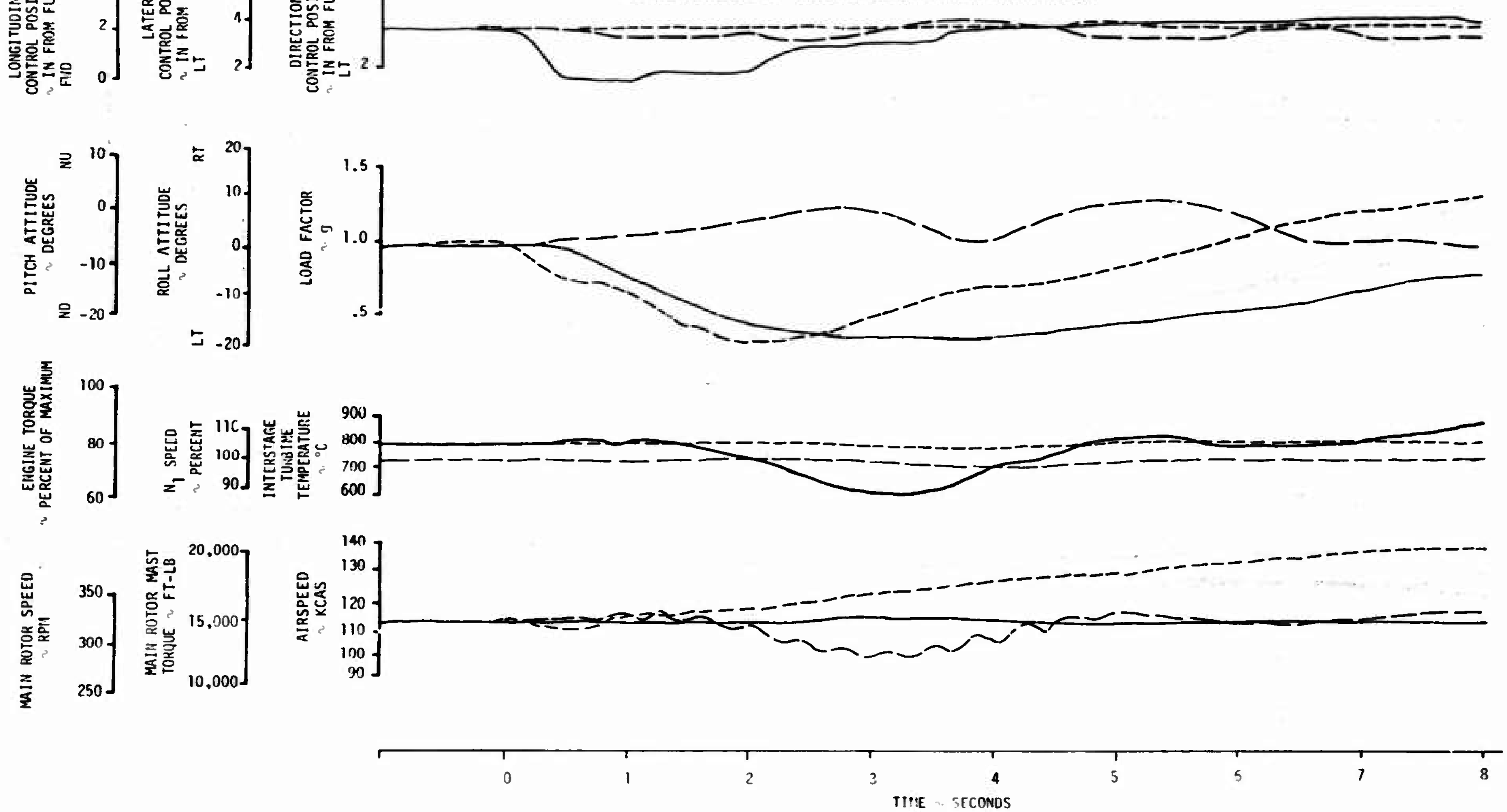


FIGURE 15
ENGINE/ROTOR CHARACTERISTICS DURING A FLARE (CONSTANT RATE)
YAH-1R USA S/N 70-15936

AVG GROSS WEIGHT ~LB	AVG CG LOCATION LONG FS	AVG CG LOCATION LAT BL	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	TRIM A/S ~KCAS	CONFIG	FLIGHT COND
9950	199.3(AFT)	-0.1(LT)	2000	23	62	HOG	LEVEL OGE

NOTE: TRIM TORQUE PRESSURE = 25 PSI.
PITCH RATE APPROXIMATELY CONSTANT

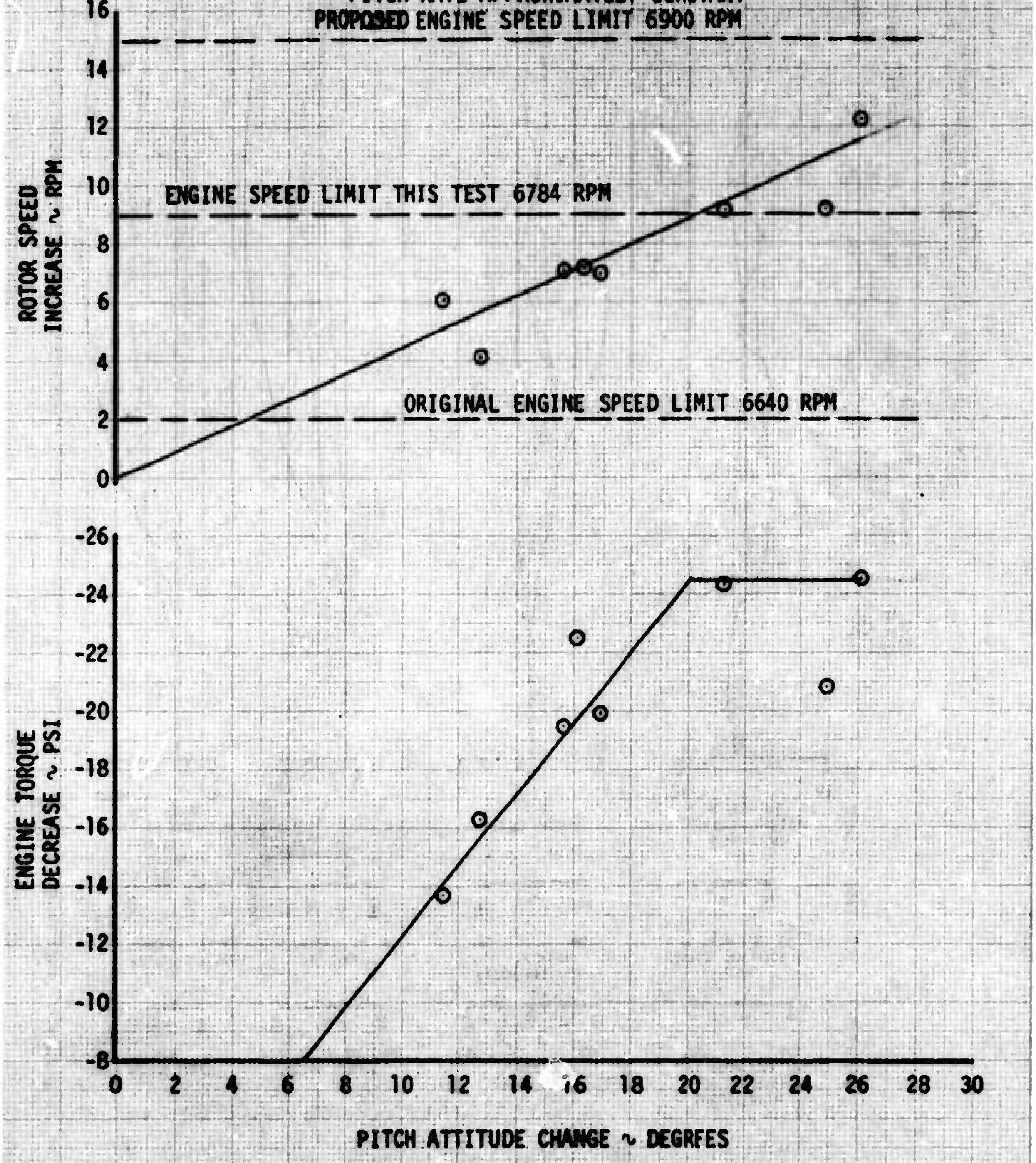
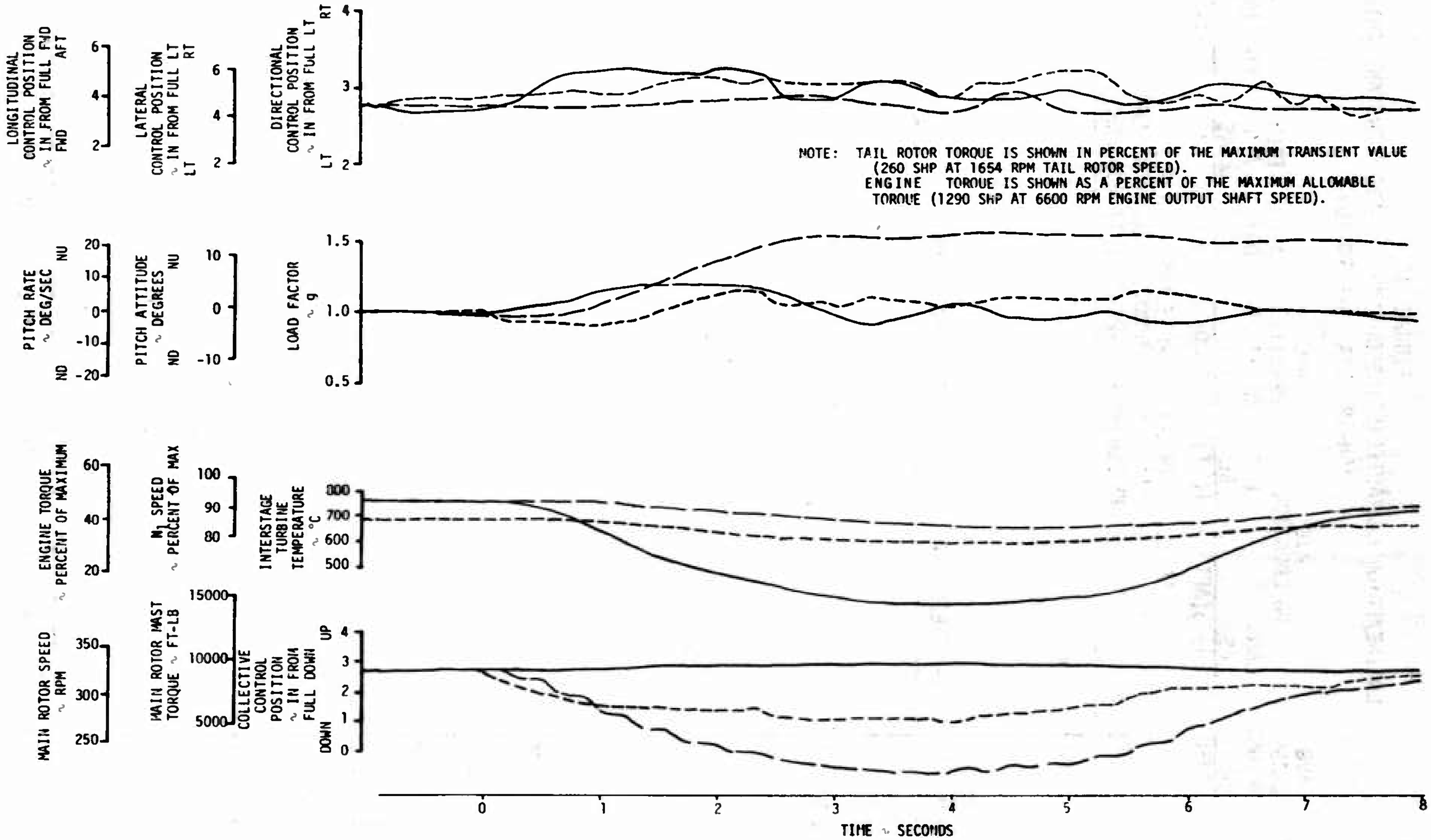


FIGURE 16
ENGINE/ROTOR CHARACTERISTICS DURING A FLARE (CONSTANT ATTITUDE)
YAH-1R USA S/N 70-15936

GROSS WEIGHT ~LB	CG LOCATION LONG FS	CG LOCATION LAT BL	DENSITY ALTITUDE ~FT	OAT ~°C	TRIM ROTOR SPEED ~RPM	C_T x10^4	TRIM AIRSPEED ~KCAS	CONFIGURATION	FLIGHT CONDITION
9800	199.3(AFT)	-0.1)LT)	2000	23	324	51.59	62	HOG	LEVEL FLIGHT



NOTE: TAIL ROTOR TORQUE IS SHOWN IN PERCENT OF THE MAXIMUM TRANSIENT VALUE (260 SHP AT 1654 RPM TAIL ROTOR SPEED).
ENGINE TORQUE IS SHOWN AS A PERCENT OF THE MAXIMUM ALLOWABLE TORQUE (1290 SHP AT 6600 RPM ENGINE OUTPUT SHAFT SPEED).

FIGURE 17
ENGINE/ROTOR CHARACTERISTIC DURING A FLARE (CONSTANT ATTITUDE)
YAH-1R USA S/N 70-15936

AVG GROSS WEIGHT ~LB	AVG CG LOCATION LONG FS	AVG CG LOCATION LAT BL	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	TRIM A/S ~KCAS	CONFIG	FLIGHT COND
9950	199.3(AFT)	-0.1(MID)	2000	23	62	HOG	LEVEL OGE

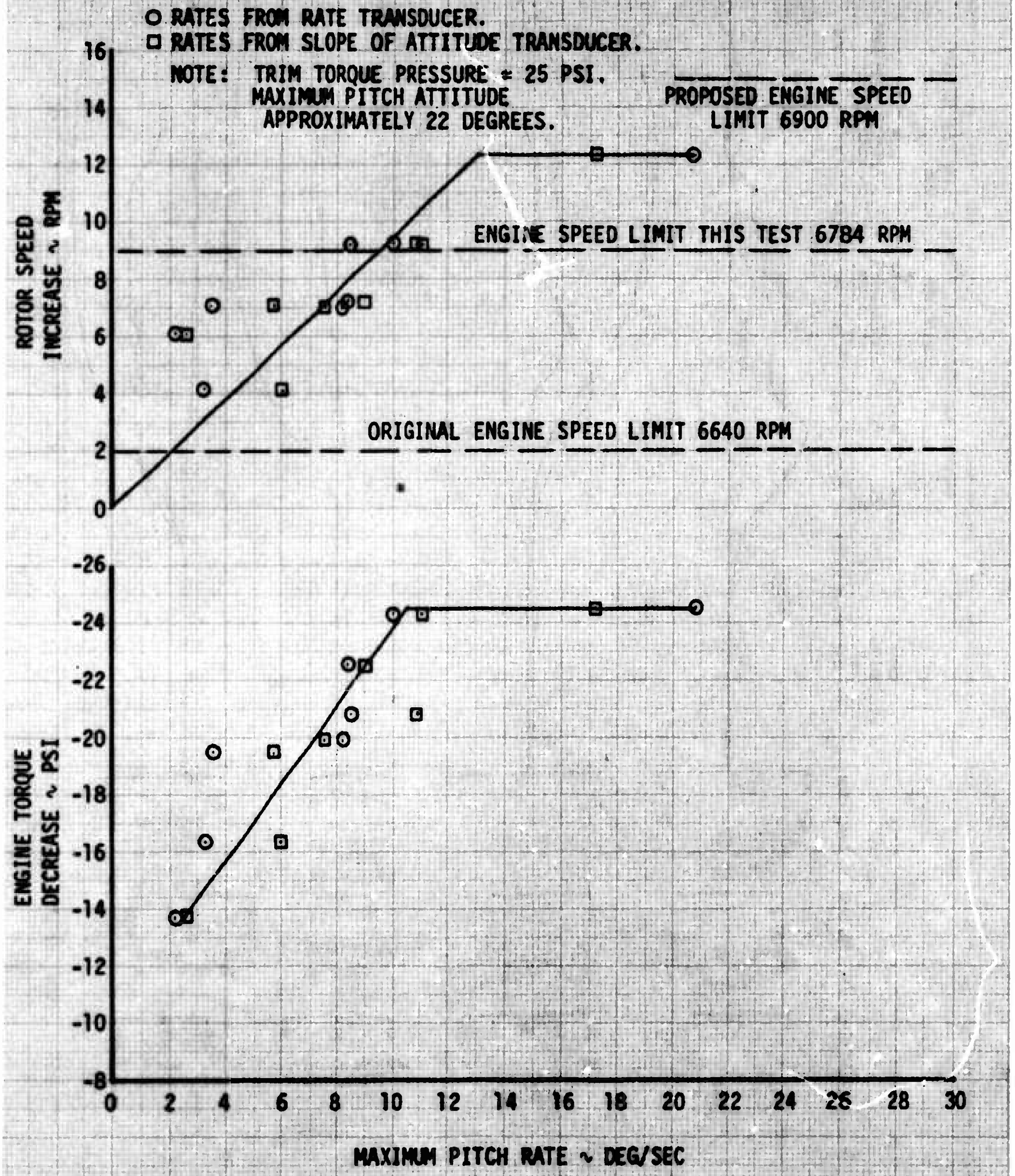
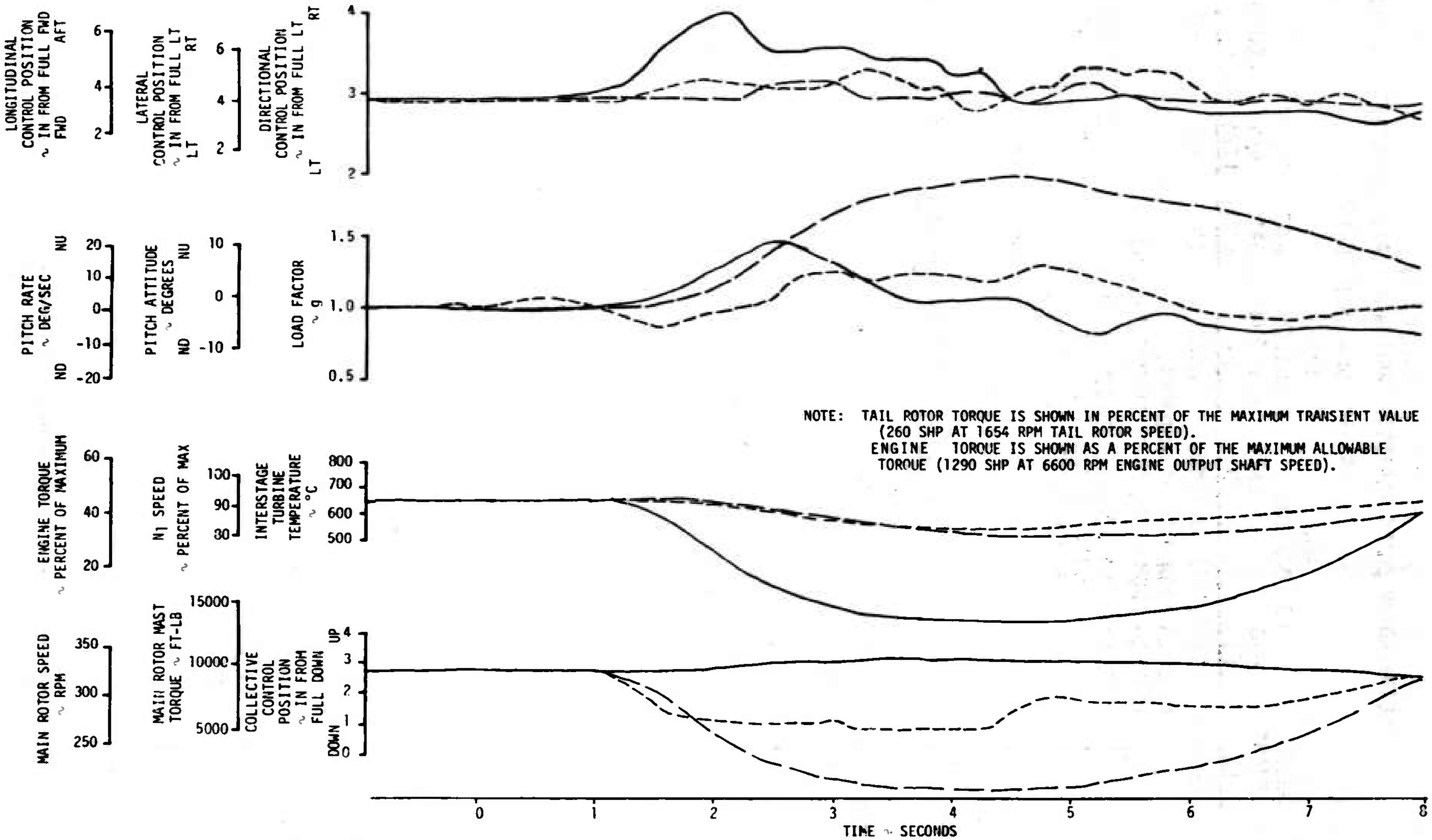


FIGURE 18
ENGINE/ROTOR CHARACTERISTICS DURING A FLARE (CONSTANT RATE)
YAH-1R USA S/N 70-15936

GROSS WEIGHT ~LB	CG LOCATION LONG FS	CG LOCATION LAT BL	DENSITY ALTITUDE ~FT	OAT ~°C	TRIM ROTOR SPEED ~RPM	C_T x10^4	TRIM AIRSPEED ~KCAS	CONFIGURATION	FLIGHT CONDITION
9750	199.3(AFT)	-0.1(LT)	2000	23	314	54.64	62	HOG	LEVEL FLIGHT



NOTE: TAIL ROTOR TORQUE IS SHOWN IN PERCENT OF THE MAXIMUM TRANSIENT VALUE (260 SHP AT 1654 RPM TAIL ROTOR SPEED).
ENGINE TORQUE IS SHOWN AS A PERCENT OF THE MAXIMUM ALLOWABLE TORQUE (1290 SHP AT 6600 RPM ENGINE OUTPUT SHAFT SPEED).

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